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MODERN HOT WATER HEATING STEAM & GASFITTING

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Hot Water Heating Steam and Gas Fitting

OVER 150 ILLUSTRATIONS

BY

WM. DONALDSON

CHICAGO
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RELATIVE ADVANTAGES OF STEAM AND HOT WATER HEATING.

The first cost of a steam heating system is from 20 to 30 per cent less than that of a hot water system. This is due to the smaller sizes of pipes and radiators used on steam work. The cost of operation is however in favor of the hot water system.

When steam radiators are shut off they cool much more rapidly than hot water radiators. This proves to be an advantage in favor of the hot water system.

A steam plant requires much more attention and skill on the part of the operator than the hot water system. With regard to freezing, the preference is in favor of steam, and in large buildings this is often a matter of great importance. A hot water system may be run during mild weather with much less heat than a steam system which must always be brought to a temperature of 212 degrees Fahrenheit before any heat is felt.

HEATING SYSTEMS.

A steam or water heating system involves in its construction the following:

A steam boiler or water heater.

387473

Pipe and pipe fittings.
Valves.
Radiators.
Air valves.

It also requires an expansion tank (water heating) for its successful operation.

A good chimney.
Good fuel.
Good management.

For heating a house or a small flat building the round sectional steam boilers or water heaters are unquestionably the best up to 1,500 square feet of radiation.

For capacities above this limitation, rectangular sectional steam boilers or water heaters are used.

Ventilation. Ventilation is a most important matter in connection with heating. All living rooms should be ventilated, and the greater the number of occupants the room contains, the greater should be the amount of ventilation required.

In the ordinary house, ventilation is obtained from the fresh air entering the rooms through the windows and doors, for the ordinary occupants of the rooms.

Under ordinary conditions, an adult requires about 1,000 cubic feet of air per hour.

The principal cause of the vitiation of the air in a room is the respiration of the occupants. Moisture and gases arising from the occupants of

the room also tend to make the air foul. Lighting and heating are other causes.

The air in a room is to some extent changed by diffusion, but preferably by the entrance through registers provided for the purpose, of fresh air that has been warmed, and by the outward passage through flues, of the foul air.

The foul air should leave a room near the floor. An open fireplace furnishes an excellent means of ventilating a room.

The foul air is heavier than the purer air, and therefore settles to the bottom of the room. By drawing the colder and therefore heavier air, which is at the bottom, the warmer air at the upper part of the room settles to fill this space, thus creating a circulation, and making the heating more effective.

Heat. In what is known as the molecular theory, all bodies are made up of rapidly vibrating particles, the hottest bodies being those whose particles move or vibrate with the greatest rapidity, and through the greatest distances. The conclusion is therefore reached that heat is not a substance, but a form of motion, and that this condition may be transferred from one body to another. This theory explains in a simple manner the various actions of heat.

Upon being heated, the particles of a body tend to repel each other, and as a result of the action of the heat the body expands, and this expansion if

carried far enough, finally produces a change in the state of the body, the point at which such change takes place varying with each different substance. As an example of this change a cake of ice when subjected to heat, melts and becomes water, and this water when subjected to further heat again changes its state and becomes steam.

Heat may be transferred from one body to another in three ways, by conduction, by convection and by radiation.

By conduction is meant the direct contact of one body with another. A heated bar of iron will transmit heat to another bar when in contact with it.

Heat is also transferred from one body to another by convection, by means of water or other fluids, which convey it from one point to another.

Heat is transferred from one body to another by radiation through such a medium as currents of air.

STEAM HEATING.

The low pressure gravity and the high pressure steam systems are the ones in general use.

The chief feature of the low pressure gravity system of steam heating is that all condensation turns to the boiler by gravity.

A pressure of steam below 10 pounds above the atmospheric pressure is low pressure steam.

The low pressure steam system is chiefly used in house heating, because it is safer than high pressure steam, and as it works at a lower pressure is more economical to use, and requires less attention.

Not less than a 1½ inch pipe should be used for a steam main, and this diameter should not be run for a greater length than 25 feet.

Regardless of the amount of work to be done, no steam riser less than 1 inch in diameter should be used.

If too small the pipes will sometimes cause the radiators to fill with water.

The steam main should be run as high as possible above the boiler. A distance of 18 inches or more should be allowed if conditions will permit of it.

Branches should always be taken from the top

of the steam supply mains or at an angle of 45 degrees, but never from the side.

Branches should not be taken from the side of the main, as water hammering and the forcing of condensed water from the main into the radiators may be result.

Branches should be run full size from the main to the risers and connected with the latter by a reducing elbow.

The horizontal branch should be one size larger than the riser, if more than 6 or 8 feet in length, as the circulation is not so strong on a horizontal as on a vertical line of pipe.

A steam main should have a pitch of at least 1 inch for every 10 feet of length.

Branches should have a pitch of at least 1 inch for each 5 feet.

Carelessness in the alignment of steam pipes is liable to form pockets or traps which will impede the circulation and cause hammering, due to the condensed water remaining in the pockets.

When necessary to make a direct rise in order to get over an obstruction or to increase the head room, the pocket formed should be dripped by a small pipe into the return.

STEAM BOILERS.

Experience has shown that steam boilers made of cast iron are the most reliable and most efficient for heating purposes. No other metals which can be used for this purpose deteriorate so little from corrosion as cast iron under like conditions. A cast iron steam boiler cannot explode. Being built up in sections they are easy to set up and involve the least amount of trouble and expense. In operation they are simplicity itself and their management is easily understood.

The capacity of a steam boiler should be at least 25 per cent in excess of the total duty required by the radiation and pipe system for direct radiation. When indirect radiation is used add 50 per cent to the above.

In locating a steam boiler, be sure and ascertain by careful measurements that will stand low enough so that the water line will be 18 inches or more below the lowest point of the steam mains.

The boiler should be placed on a solid foundation and as close as possible to the flues.

The proper size of coal to use in a given size of steam boiler is a very important factor to its successful operation. As a rule the best results have been obtained by the use of range or stove coal in

round boilers or heaters. For rectangular steam boilers good results have been obtained by the use of stove coal for the smaller sizes and egg coal for the larger ones. If bituminous or soft coal be

Fig. 1.

used instead of anthracite or hard coal, a boiler at least one size larger should be installed.

Round Steam Boilers. The boiler shown in Fig. 1 is entirely of cast iron construction, so arranged

as to amply provide for expansion and contraction. The only joints or connections are formed of heavy cast iron threaded nipples, making a perfect joint, with no possibility of leaks from any cause whatsoever and absolute freedom from all necessity of packing of any kind. The general construction of both steam boilers is as follows:

The circular base, or ashpit, which also forms the support for the grate, is substantially made of cast iron and gives a safe depth for accumulation of ashes. Resting on this is the firepot section, shown in Fig. 2. This section, being one complete casting in itself, and tested under heavy pressure before leaving the shop, is absolutely free from mechanical imperfections. In the center of the top of this section is a large opening, threaded to receive a nipple, which connects it with a closed section, shown in the right hand upper view, Fig. 2. This first, or intermediate section, is of less diameter than the top of the firepot section. On top of this closed, or intermediate section and attached to it in the same manner, as described for the connection of the firepot, there is an open section shown in the right hand upper view, Fig. 2, which is of the same diameter as the top of the firepot and entirely fills the jacket casings hereinafter described. On top of this is placed another closed section, and on top of this again comes the top section, which is either the steam dome, forming the steam boiler,

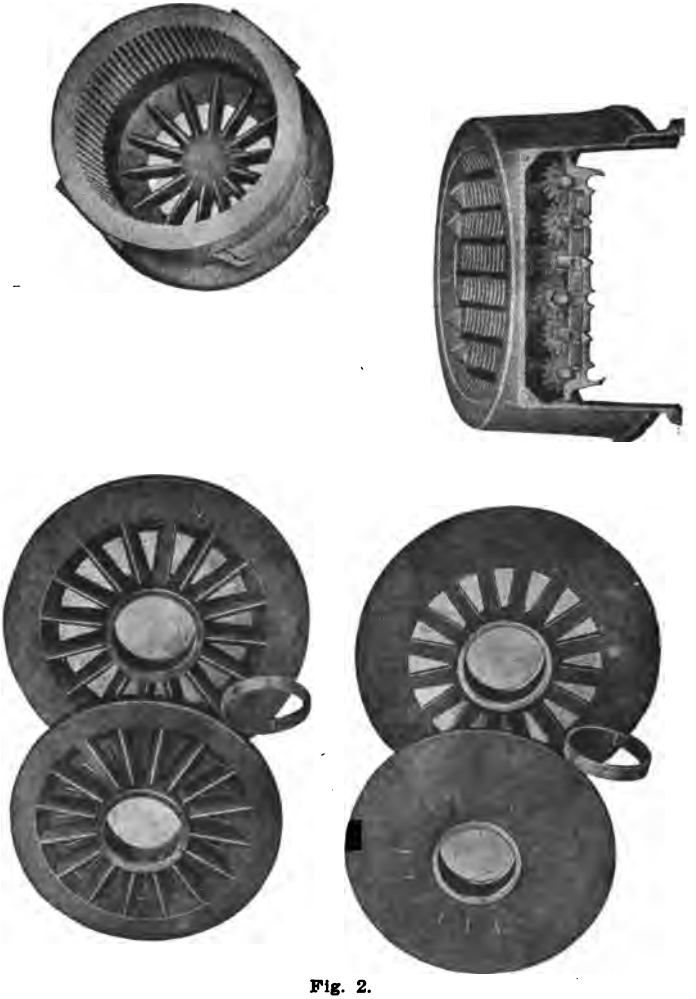


Fig. 2.

or the upper water section, forming the water heater, all connected together in the manner de-

scribed, with screw nipples, the top section, or dome, having the necessary tappings for the supply outlets for steam, or the flow outlets for water.

Casings. Extending from the outer edge of the top of the firepot section to the top of the upper section, or dome, there are cast iron casings, closely fitted joints. These casings are made in segments and are interchangeable and easily applied, with no possibility of rusting, wearing out or breaking. They form in themselves a perfect chamber for the retention of products of combustion, compelling these to follow such channels as will give best results.

Firepot. The firepot is circular in form, entirely surrounded by water, is made in one perfect casting, and free from any possible chance of leakages. The inner surface of the firepot has projecting into it all around the sides a multiplicity of iron points, just long enough to prevent the water contact from chilling the fire and making it possible to secure perfect combustion and a uniform fire around the edges as well as in the center. The firepots are of sufficient depth to insure a deep, slow fire, forming the best and most economical heat-producing proposition for low pressure heating.

Grate. The grate is of the triangular form and is at all times easily operated, and in its operation it pulverizes all clinkers before depositing in ash pit.

On all the larger size boilers the grates are fitted with a heavy bearing bar in the center, thus prolonging the life of the grate bars, as it prevents their warping.

Simplicity of the Grates. The construction of the grate is exceedingly simple, and admits of any one bar of the whole grate being changed without the assistance of skilled labor.

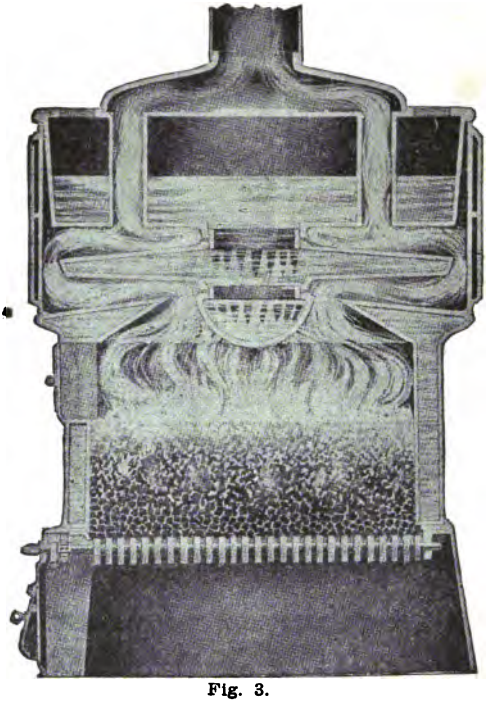


Fig. 3.

Fig. 3 shows a vertical cross-section of a steam boiler.

Rectangular Sectional Boilers. The vertical sectional type of steam boiler has been on the market and in all forms for a number of years. There are no new ideas that can be safely exploited in this line. The demand is for a simple, practical, easily handled device that will absolutely endure the work appropriated for it.

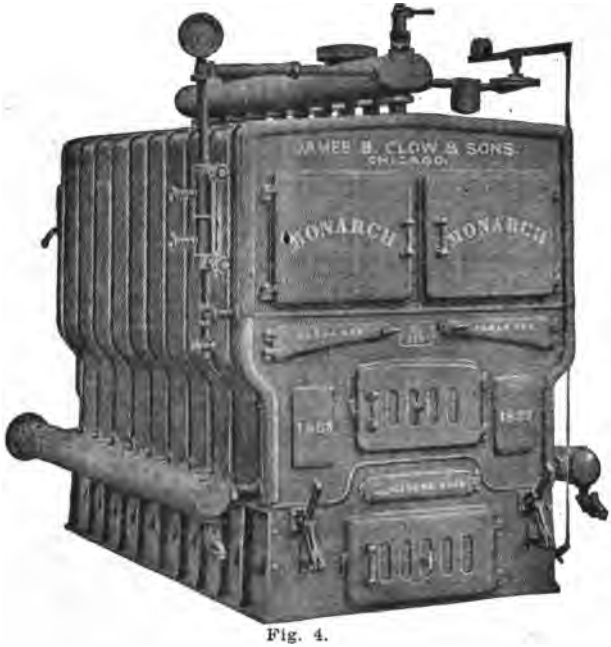


Fig. 4.

The boiler shown in Fig. 4 is strong, of good appearance, thoroughly accessible for cleaning, and, so far as can be determined from exterior appearances, a most satisfactory heater. The good opin-

ion already formed of the heater is further strengthened by reference to views of the intermediate and rear sections shown in Figs. 5 and 6. By reference to these cuts it will be seen that every possible advantage is taken of the fire surface, it being the belief that, unless great good is

Fig. 5.

accomplished in direct contact with the fire, there will be but little assistance obtained from the flues.

Firepots. Firepots of the type of heaters are deep—to give a compact body of fire, and, besides, are covered with numbers of iron projections to prevent chilling contact of the fire with the ex-

posed water surface and yet secure such perfect combustion as will quickly impart to the water the heat from the fuel and permit of maintaining at all times a clear, even fire in every portion of the firepot.

Fig. 6.

Boiler capacity. The capacity of the boiler should be at least 20 per cent in excess of the total duty imposed upon it by the radiation and pipe system.

Example: Let 600 square feet equal the total radiation, plus 25 per cent for the surface of the mains, plus 20 per cent excess boiler capacity, which is 900 square feet, the capacity of the boiler

required. The same result may be arrived at by adding 50 per cent to the radiation.

When direct-indirect radiation is used, an ad-

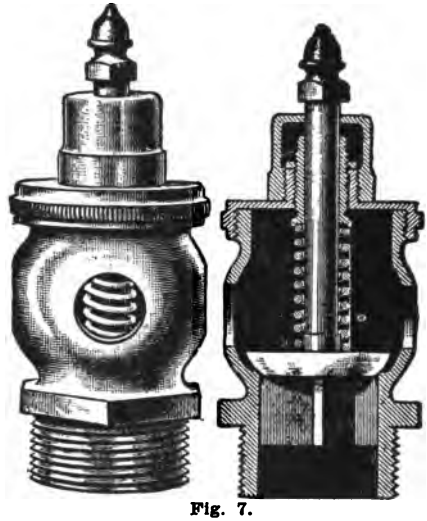


Fig. 7.

ditional 33 1/3 per cent must be allowed, and when indirect radiation is used, add 50 per cent.

Example:

Total direct radiation	450	sq. ft.
One direct-indirect radiator	60	" "
One indirect radiator	90	" "
	600	" "
25 per cent for surface of mains	112.5	" "
33 1/3 per cent on direct-indirect	20	" "
50 per cent on indirect radiator	45	" "
	777.5	" "
20 per cent excess capacity	155.5	" "
Boiler capacity	933	" "

Safety Valves. While not an absolute necessity, some form of low-pressure safety valve is generally used on the steam boiler of a low-pressure heating plant. Forms of low-pressure safety

Fig. 8.

valves are shown in Figs. 7 and 8, the one shown in Fig. 7 is spring controlled and capable of adjustment for different pressures, while that shown in Fig. 8 has a ball weight instead of a spring

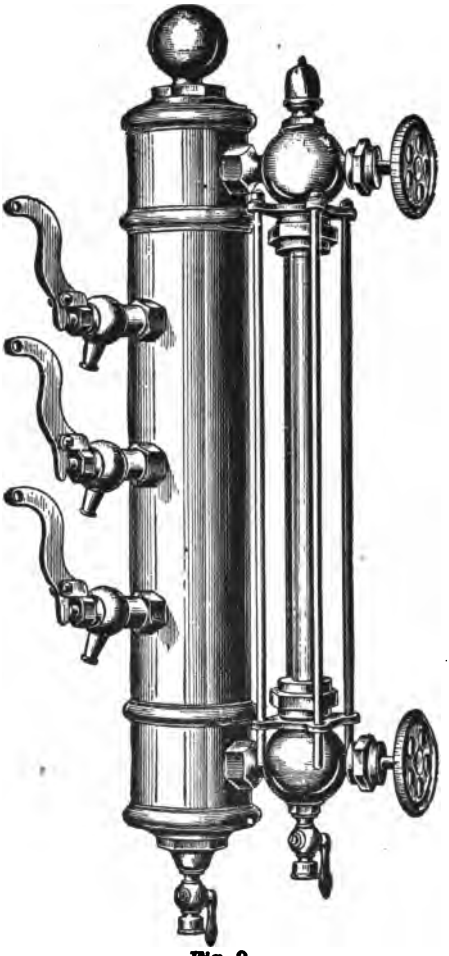


Fig. 9.

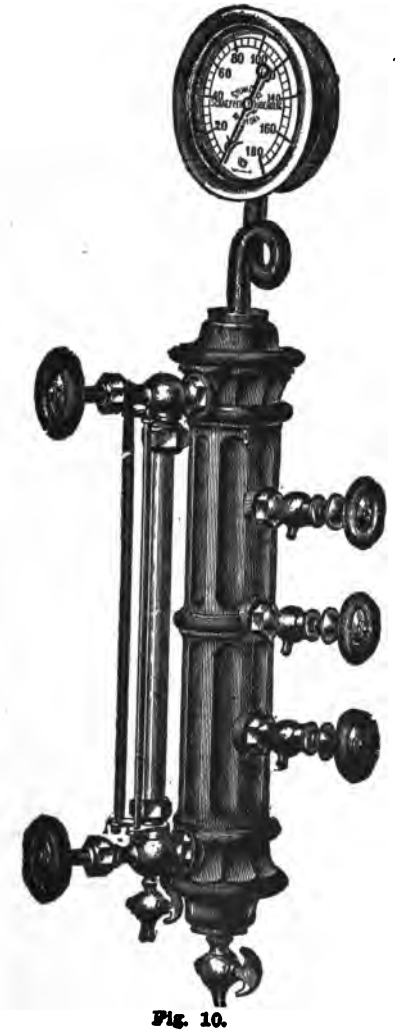


Fig. 10.

and is consequently non-adjustable except by changing the weight.

Water Column. Every steam boiler should be equipped with a water column with water gauge and try-cocks as shown in Fig. 9. A combination water column is shown in Fig. 10, with steam gauge on the top of the column.

Damper Regulator. While an automatic damper regulator is not as essential to a water heater as to a steam boiler, it is a very useful device, and when used prevents overheating and occasions great economy in fuel. An automatic regulator for a steam boiler is shown in Fig. 11. Check draft

Fig. 11.

dampers, which are controlled by automatic regulators, are shown in Fig. 12.

The damper regulator consists of a hollow bowl formed by two castings bolted together, with a rubber diaphragm between them, the lower casting being connected to the steam space of the boiler by means of a short nipple. Through an opening in the top of the upper casting a plunger works, and across this plunger and connected to an upright lip on the edge of the diaphragm cast-

ing is a bar, from the ends of which chains connect to the draft door and check damper door of the boiler.

As the steam pressure rises, the pressure against the under side of the rubber diaphragm is transmitted to the plunger which is raised,

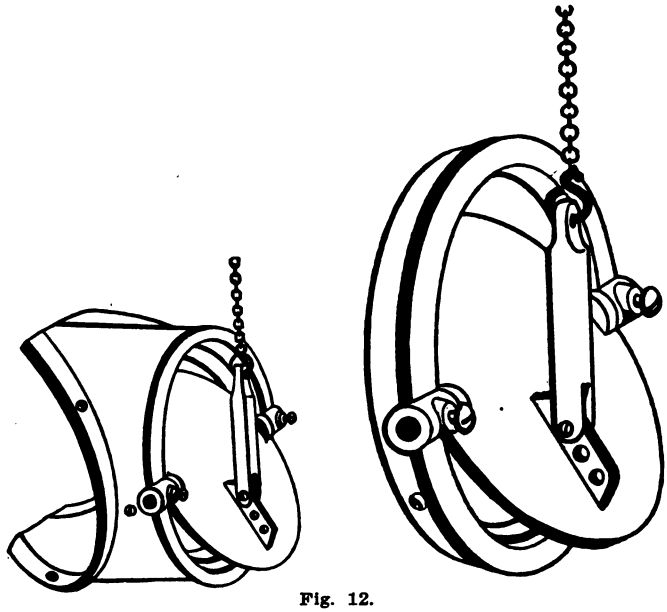


Fig. 12.

thereby operating the rod or lever, and the chains connecting with the draft and check damper doors. The sliding weight usually on the rod may be set so that the leverage may be smaller or greater, according to the pressure of steam carried on the apparatus, before the operation of

the doors will take place. By means of the damper regulator the rise and fall of temperature in the boiler may so regulate the draft that an even temperature may be obtained.

The chains should be so set that the draft door and check draft will each be closed when the regulator lever is level, and there is no steam in the boiler.

Pressure Gauges. The hollow spring in the gauge, shown in Fig. 13, is so shaped and arranged

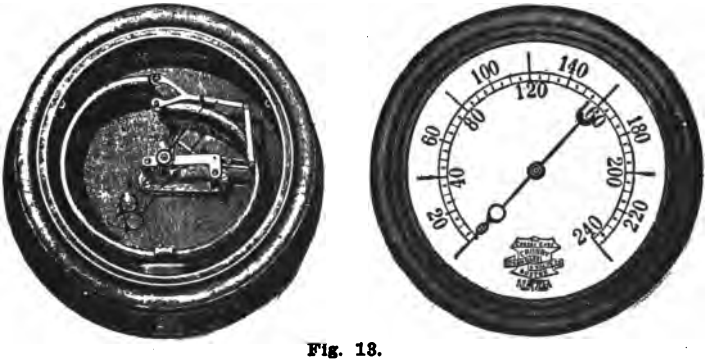


Fig. 13.

and the mechanism is such that the vertical as well as the horizontal movement of its free ends is fully utilized. It thereby permits the use of springs 100 per cent stronger than can be used in any other gauge, so preventing their settling under any pressure which may be indicated upon its dial.

The gauge shown in Fig. 14 may be used for

indicating either pressure or vacuum, as the case may be. It is graduated for pressure in pounds per square inch, and for vacuum in inches of mercury in column or pounds per square inch, as may be desired.

Fig. 14.

Smoke Pipes. Steam boiler smoke pipes range in size from about 8 inches in the smaller sizes to 10 or 12 inches in the larger ones. They are generally made of galvanized iron. The pipe should be carried to the chimney as directly as possible, avoiding bends, which increase the resistance and diminish the draft. When the draft is known to be good the smoke pipe may purposely be made longer to allow the gases to part with more of their heat before reaching the chim-

ney. Where a smoke pipe passes through a partition it should be protected by a double perforated metal collar at least 6 inches greater in diameter than the pipe.

The top of the smoke pipe should not be placed within 8 inches of exposed beams nor less than 6 inches under beams protected by asbestos or plaster. The connection between the smoke pipes and the chimney frequently becomes loose, allowing cold air to be drawn in, thus diminishing the draft. A collar to make the connection tight should be riveted to the pipe about 5 inches from the end, to prevent its being pushed too far into the flue.

Chimney Flues. Flues, if built of brick, should have walls 8 inches in thickness, unless terra cotta linings are used, when only 4 inches of brick work is required. Except in small houses, where an 8x8 flue may be used, the nominal size of the smoke flue should be at least 8x12, to allow a margin for possible contractions at offsets, or for a thick coating of mortar. A clean out door should be placed at the bottom. A square flue cannot be reckoned at its full area, as the corners are of little value. An 8x8 flue is practically very little more effective than one of circular form 8 inches in diameter. To avoid down drafts the top of the chimney should be carried above the highest point of the roof, unless provided with a suitable top or hood.

Dimensions of Chimney Flues for Given Amounts of Direct Steam Radiation

Square Feet of Steam Radiation	Diameter of Round Flue	Square or Rectangular Flue
250	8 inches	8 in. x 8 in.
300	8 inches	8 in. x 8 in.
400	8 inches	8 in. x 8 in.
500	10 inches	8 in. x 12 in.
600	10 inches	8 in. x 12 in.
700	10 inches	8 in. x 12 in.
800	12 inches	12 in. x 12 in.
900	12 inches	12 in. x 12 in.
1000	12 inches	12 in. x 12 in.
1200	12 inches	12 in. x 12 in.
1400	14 inches	12 in. x 16 in.
1600	14 inches	12 in. x 16 in.
1800	14 inches	12 in. x 16 in.
2000	14 inches	12 in. x 16 in.
2200	16 inches	16 in. x 16 in.
3000	16 inches	16 in. x 16 in.
3500	18 inches	16 in. x 20 in.
5000	18 inches	16 in. x 20 in.

Fuel Combustion. Combustion is one form of chemical action, accompanied by the generation of heat. When such action takes place slowly the heat produced is almost imperceptible, but when it takes place rapidly, as in the burning of wood, coal, etc., the heat becomes intense. In the burning of ordinary fuel, the carbon and hydrogen of the coal combine with the oxygen of the air and produce combustion, without which no material results may be obtained from the fuel.

Combustion depends upon the presence of oxygen, without which it cannot take place.

Combustion is estimated by the number of pounds of fuel consumed per hour by one square foot of grate surface.

One square foot of grate will consume about 5 pounds of hard coal per hour, or about 10 pounds of soft coal, under a natural draft.

For 7½ to 10 pounds of coal consumed, one cubic foot of water will be evaporated.

A fire of a depth of 12 inches will do more efficient work than one of less depth.

The use of too large coal is attended with large air spaces between the pieces, and this large amount of air is too great for the gases escaping from the combustion of the coal, allowing the gases to escape into the chimney flue unburned.

The use of too small coal is not advisable, as it packs down so compactly as to prevent the admission of the proper amount of air through the grate to produce good combustion.

Pipe Systems. The three systems of heating described: The direct, indirect and direct-indirect radiation, are governed by the same rules in the matter of piping and steam supply, requiring only special rules for proportioning the amount of heating surface and for the arrangement of air supply. There are the one-pipe and two-pipe systems, with several forms and combinations of each, and for the steam supply there are high and low-pressure systems, exhaust systems, gravity systems and vacuum systems.

The essentials of a heating system are: A source of steam supply, a system of piping to conduct the steam from the source of supply to the radiators, a series of radiators or radiating surfaces, a system of return pipes through which the condensed water from the radiators may be removed.

It may be more briefly stated that the prime requisites for a steam heating system are: The source of steam supply, the radiating surface and a system of pipes connecting them. Should, however, the supply and return pipes be embodied in the same system, it is just as important to arrange to dispose of the condensed water as it is to supply steam to the radiators.

One-pipe System. The simplest form of steam heating system is known as the one-pipe gravity return system. The steam is generated in the

boiler, flows through the pipes to the radiators, the condensed water as it is formed in the radiators draining out along the bottom of the pipes and back to the boiler by gravity, to be re-evapor-

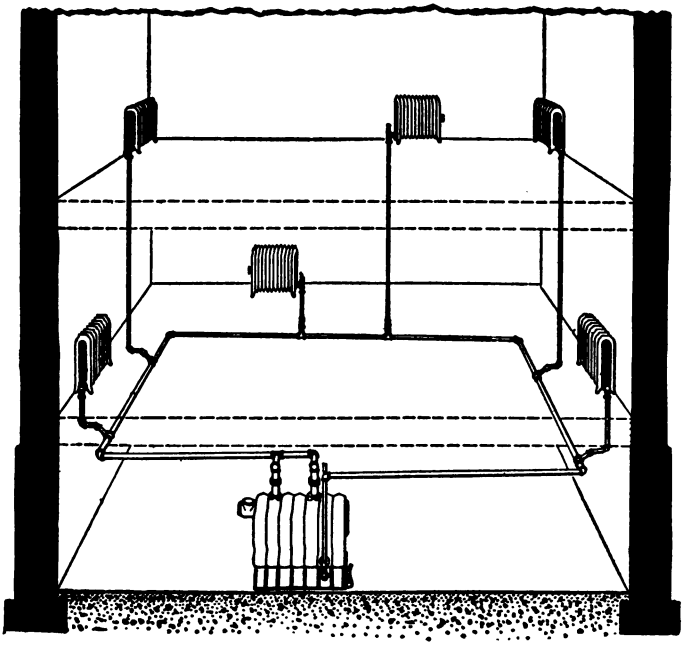


Fig. 15.

ated into steam. This system may be used only in a very small plant, and one in which the pipes should be made of large size and given a very decided pitch toward the boiler.

One-pipe System With Separate Return. In the system shown in Fig. 15 the main in the base-

ment is pitched so as to drain away from the boiler, and at its end a return pipe is connected and led back to the boiler, entering it below the water-line. In this manner the flow of the steam and the water of condensation is in the same direction in the mains, and upon the sudden condensation of steam, as occurs when turning steam into a cold radiator, the water falls down the risers against the current of steam, while in the main it is forced along in the same direction as the steam. If the mains are extensive they may be drained at different points. This system is extensively used for residences and buildings of only a few stories in height, and it has also been used in larger installations. In such a plant the risers as well as the mains must be of ample size, and the latter must have sufficient pitch and be thoroughly drained.

One-pipe Overhead System. This is the only system of single-pipe connection which is extensively used in high buildings, such as the modern office building, and is shown in Fig. 16. In this system the steam is conducted through a large main supply pipe to the attic of the building, or to the ceiling of the top floor, and from this the mains extend around the building to supply the risers. The risers are connected with the return mains in the basement. In this system the flow of steam and condensed water is everywhere in the same direction except in the connections to the

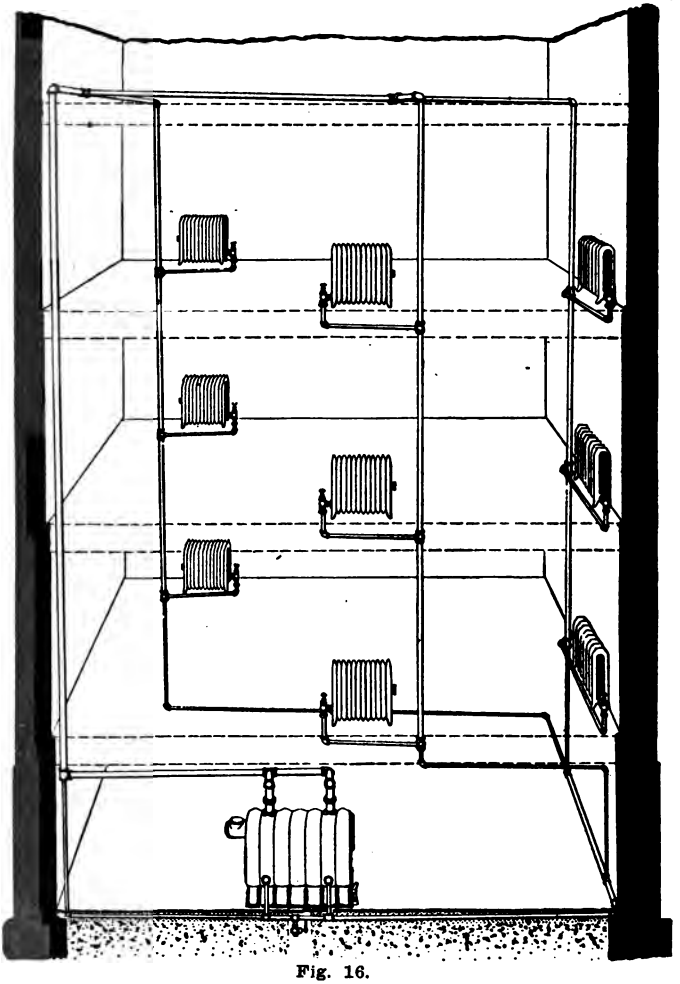


Fig. 16.

radiators, and the risers should be so arranged that these connections may be comparatively

short. This system has the very decided advantage over the ordinary one-pipe system that the condensed water which falls down the risers from the radiators does not, when it reaches the horizontal pipe at the bottom come into contact with the main current of steam, as the horizontal pipe is only a drain in which there is practically no steam and which is intended solely for the purpose of draining of the condensed water.

Two-pipe System. The two-pipe system is illustrated in Fig. 17 is much the same in all cases, but special adaptations of it are sometimes made to meet special conditions. There is a two-pipe overhead system in which steam mains are in the attic as well as in the one-pipe overhead, but there a separate set of return risers are provided which connect with the return in the basement. This system has been very little used.

The One-pipe Circuit Steam Heating System. In this system the steam pipe is run from the boiler vertically to the ceiling of the basement, from which point it pitches downward throughout its course around the cellar or basement, to a point at or near the rear of the boiler, where an automatic air vent is placed, and drop made with a pipe into the return opening of the boiler.

The one-pipe circuit system is used in buildings which are square or rectangular in shape.

When the building is of such shape that a one-pipe circuit will not do the work to advantage,

that is to say, in long buildings, where the boiler is set at or about the middle of the building, it is then desirable to run a loop in either direction.

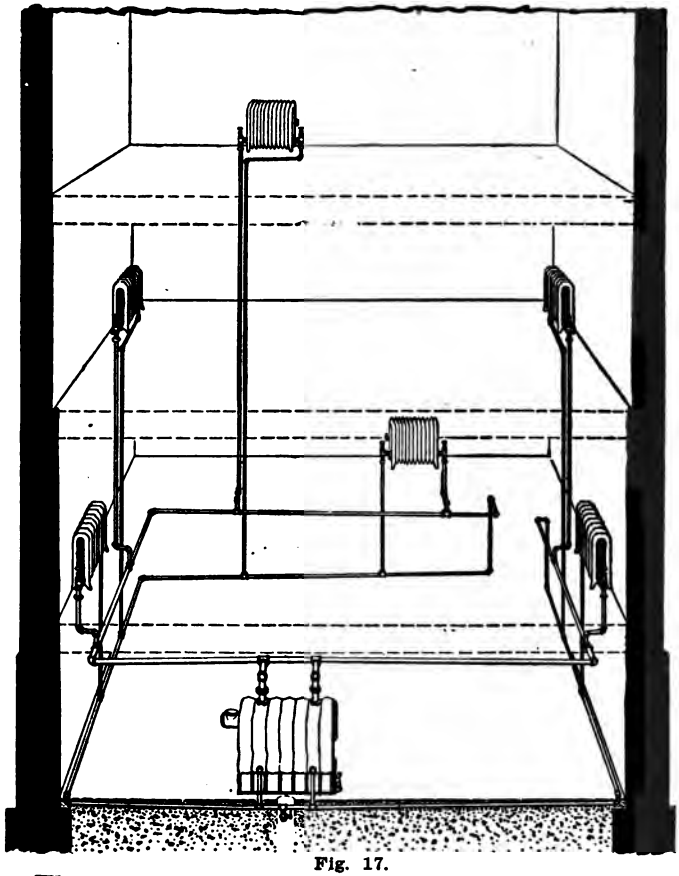


Fig. 17.

The Overhead Steam Heating System. In this system the feed pipe is carried vertically to the

ceiling of the top floor, or into the attic, and from this point branches are carried down to the different radiators.

This system is used in office buildings, school houses, factories, and often in residences, when a main can be carried up into an attic. Frequently, owing to the absence of a basement under the building, it is necessary to use the overhead system to heat the radiators.

The return pipes should enter the top of the flow end of the radiator, and return out of the bottom of the return end.

Some radiators on the one-pipe system may be connected as single pipe. Radiators on the overhead system may also be connected as on a one-pipe circuit system. Where this is done, the condensed water from the radiator returns into the drop or feed pipe.

Heating Surface. To estimate the amount of heating surface required to heat a room with steam to a temperature of 70 degrees Fahrenheit in zero weather with a steam pressure of from 2 to 3 pounds and ordinary conditions of exposure, the following rule is given, which is for direct radiation, and based upon the glass surface, exposed wall surface and cubic space:

1 square foot of radiation to 3 square feet of glass.

1 square foot of radiation to 10 square feet of wall exposed.

1 square foot of radiation to 150 cubic feet of space.

For each degree of temperature above or below zero, deduct from or add to 1½ per cent of the radiation given by the above rule.

Example: Required the number of square feet of direct radiation for a room 10x10x10 feet, having two exposed sides and two windows 2½x6 feet.

Answer:

Glass surface=	30	sq. ft.÷	3=	10	sq. ft.
Exposed walls=	200	" " ÷	10=	20	" "
Cubic space=	1,000	cu. " ÷	150=	6.6	" "
		Total direct radiation=		36.6	sq. ft.

Example: Required the number of square feet of direct radiation for the same room, with one exposed side and one window 2½x6 feet:

Answer:

Glass surface=	15	sq. ft.÷	3=	5	sq. ft.
Exposed walls=	100	" " ÷	10=	10	" "
Cubic space=	1,000	cu. " ÷	150=	6.6	" "
		Total direct radiation=		21.6	sq. ft.

When indirect radiation is used, 50 per cent should be added to the above figures.

Reducing Size of Steam Mains. The proper reductions in the size of pipe depend on the character of the work to which the pipe is put.

It is customary to rduce the size of mains by

using reducing fittings tapped eccentric, or by using a reducing coupling tapped eccentric, the idea being to have a continuous fall of pipe without the formation of traps or obstructions for holding water at the points where reductions are made. It is customary to reduce the size of pipes for risers or radiator connections by using a reducing ell on the branch under the floor.

Eccentric fittings are so tapped as to bring the bottoms of the openings of different sizes at the same level on the fitting. When these fittings are used they allow a continuous fall of pipe without forming pockets for holding water at the points where reduction in size is made. This is of material benefit to a heating system.

Steam Mains. The proper size of steam mains for one and two-pipe systems are given in the accompanying tables:

Proper Size of Steam Mains:

ONE PIPE SYSTEM

Pipe Size in Inches	2	2½	3	3½	4	4½	5	6
Sq. feet of Radiation	200 to 350	350 to 500	500 to 750	750 to 1000	1000 to 1500	1500 to 1800	1800 to 2200	2200 to 3000

TWO PIPE SYSTEM

Pipe Size in Inches	2	2½	3	3½	4	4½	5	6
Sq. feet of Radiation	500	750	1000	1500	2000	2500	3000	4000

RADIATION.

Direct Radiation. This consists of a heating surface in the form of a radiator or coil, which is placed directly in the room to be heated.

Indirect Radiation. Radiators in the room to be heated on the first or second floor are located in the cellar or basement, usually directly under the rooms to be heated. There is placed in the floor of the room to be heated, or in the side wall above the baseboard, a register and connection is made between this register and the radiator in the basement by means of tin or sheet iron pipe, for conveying the heated air into the room.

The indirect radiator is placed in a chamber into which fresh air is conveyed from outside, and to which the hot air flue to the register is connected.

The distance from the top of the radiator to the ceiling of the casing should be from 10 to 12 inches and from the bottom of the radiator to the bottom of the casing from 6 to 8 inches. The dimensions of the cold air inlet should be 1½ square inches for each square foot of indirect radiation. The warm air outlet should be 2 square inches for each square foot of indirect radiation, which would be for a radiator containing 100 square feet of

radiation, 200 square inches of cross sectional area, or a duct 10x20 inches. The dimensions of the warm air register should be 50 per cent larger than those of the warm air duct, which allows for the contracted area caused by the register face. A warm air duct having 200 square inches of cross sectional area should have a register approximating 300 square inches.

Direct-Indirect Radiation. This system serves a double purpose, that of Direct Radiation and Ventilation, and is also placed in the room to be heated under windows, or close to the exposed walls.

The lower front part of the radiator is encased, having an opening at the bottom or back of the base for the introduction of cold air by means of a duct through the outside wall of the building.

On account of the cooling effect of the outside air passage between the coils of the radiator, increased heating surface to the amount of 33 1/3 per cent must be added to make it equivalent to direct radiation.

This system of radiation is seldom used in the heating of houses, being more necessary where ventilation is required in the heating of public buildings and schools.

Instead of placing all of the radiators at one point, it is well to divide it into two or more radiators, according to the size of the room. As heating with steam or hot water is accomplished by the

turning or circulation of the air in the room, it is well to divide and place the radiation at the most exposed points, in order to better heat the room.

In small houses a radiator placed in the lower hall, if sufficiently large, will heat the hall above, but in large buildings, where the hall space is large, the upper halls should have radiators placed in them.

A properly installed steam heating plant should be noiseless in operation and heat the rooms to 70 degrees in zero weather on from 2 to 3 pounds steam pressure, and show a circulation of steam throughout the system on a pressure of 1 pound, as indicated by the steam gauge.

A noiseless circulation in all radiators on a pound of steam or less indicates that the pipe system is of proper size and properly pitched, thereby avoiding low places, causing water pockets or traps. The proper heating of the rooms in which the radiation is placed on from 1 to 3 pounds steam pressure indicates that the heating surface or radiation is sufficient.

Radiators. Heating surfaces are divided into three classes: Direct radiation, Indirect radiation and Direct-indirect radiation.

Direct radiation covers all radiators placed within a room or building to warm the air, and are not connected with a system of ventilation.

The best place within a room to place a single radiator, is where the air is cooled, before or under

the windows, or on the outside walls. When the radiator is of vertical tube, or a short coil, which can occupy only the space under one window, and when, as often occurs, there are three windows, the riser should be so placed as to bring the line of radiators in front of, and under the windows where they will do the most good. When a small extra cost is not considered, to use two radiators and place one in front of each of the extreme windows.

When the room is large and has many windows, the heating surface, when composed of radiators, should be divided into as many units as possible.

Indirect radiation embraces all heating surfaces placed outside the rooms to be heated, and can only be used in connection with some system of ventilation.

All the heating surface is placed in a chamber, and the warmed air distributed through air ducts.

Figs. 18, 19 and 20 show two, three and four column forms of direct radiators, and Fig. 21 a two-piece hall or window direct radiator.

The indirect radiator is usually boxed, either in wood lined with tin, or in galvanized iron. The former is best when the basement is to be kept cool, as there is a greater loss by radiation through metal cases, otherwise the sheet metal is the best, as it will not crack.

Indirect radiators are usually hung from the ceiling in the basement under the rooms they are

intended to heat. A cold air duct is carried from an opening in the outside wall to the stack box.

Fig. 18.

This duct must be provided with a damper, and its inlet covered on the face of the outside of the wall with a wire screen of small mesh.

Fig. 19.

The box inclosing the radiator shown in Figs. 22 and 23 is made of wood lined with bright tin about half-way down. The sides of the box should

Fig. 20.

almost touch the hubs of the radiator on both ends, so that the cold air coming in through the duct will surely find its way up between the sections of the radiator, and not around the ends of it.

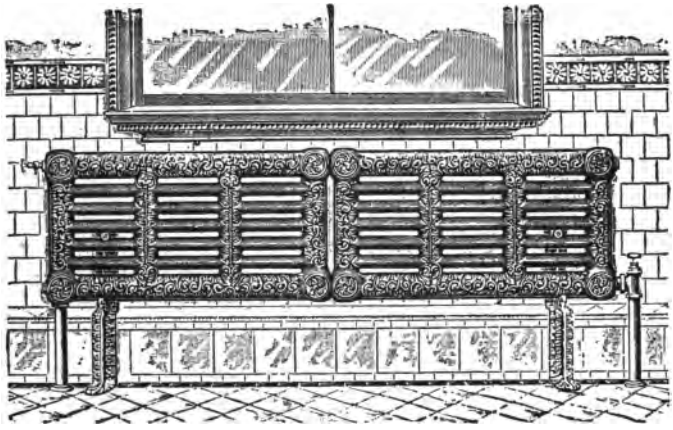


Fig. 21.

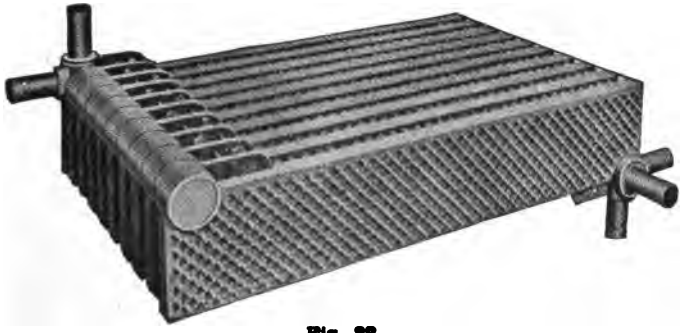


Fig. 22.

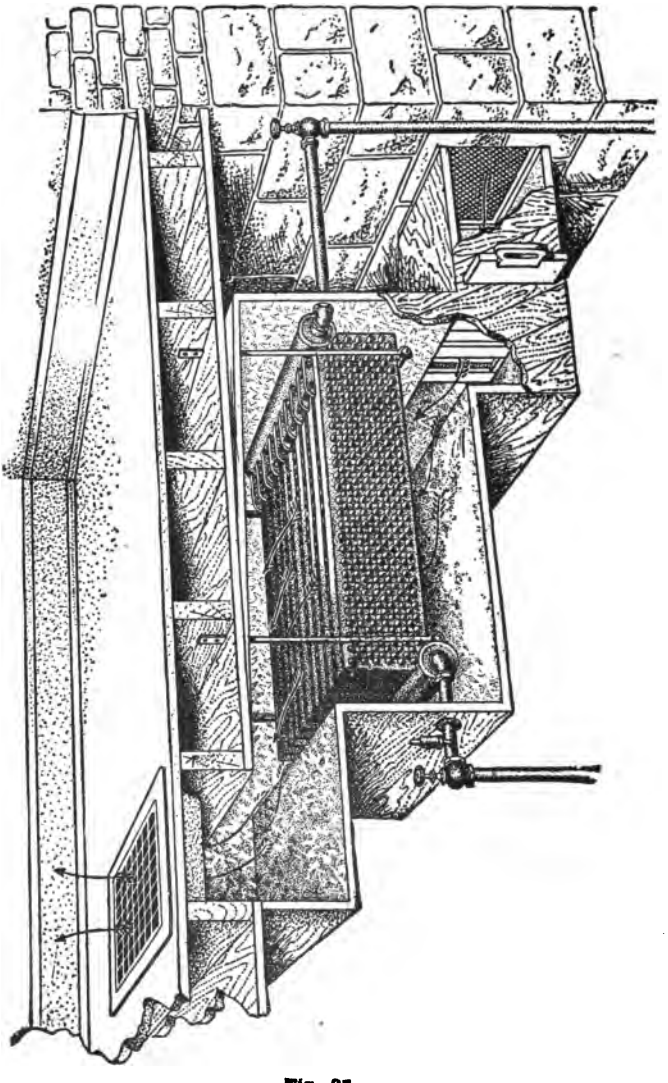


Fig. 23.

The radiator is shown connected for a two-pipe steam system.

The cold air duct is provided with a slide, so that the air may be shut off when it is not wanted, or when the radiator is turned off. The radiator

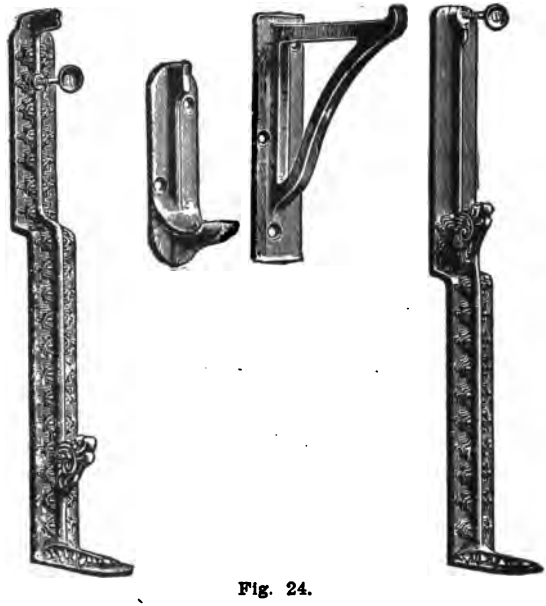


Fig. 24.

should be so hung in the box that the space above it is about one-third more than the space below; this provides for the expansion of the air after it has been warmed by contact with the radiator.

Brackets for supporting the hall or window types of direct radiator are shown in Fig. 24.

A direct-indirect form of radiator is illustrated in Fig. 25, in which the air is taken from the outside of the room to be heated and passes up between the sections of the radiator as shown, the front of the radiator being encased.

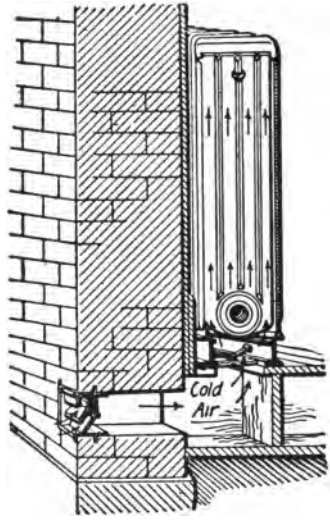


Fig. 25.

TWO COLUMN RADIATOR FOR STEAM OR HOT WATER HEATING.

No. of Sections.	Length in Inches.	SQUARE FEET OF HEATING SURFACE.					
		45 Inches High.	38 Inches High.	32 Inches High.	26 Inches High.	23 Inches High.	20 Inches High.
2	5	10	8	6⅔	5⅓	4⅜	4
3	7½	15	12	10	8	7	6
4	10	20	16	13⅓	10⅔	9⅛	8
5	12½	25	20	16⅔	13⅓	11⅜	10
6	15	30	24	20	16	14	12
7	17½	35	28	23⅓	18⅔	16⅓	14
8	20	40	32	26⅔	21⅓	18⅜	16
9	22½	45	36	30	24	21	18
10	25	50	40	33⅓	26⅔	23⅛	20
11	27½	55	44	36⅔	29⅓	25⅜	22
12	30	60	48	40	32	28	24
13	32½	65	52	43¼	34⅔	30⅓	26
14	35	70	56	46⅔	37⅓	32⅜	28
15	37½	75	60	50	40	35	30
16	40	80	64	53⅓	42⅔	37⅛	32
17	42½	85	68	56⅔	45⅓	39⅝	34
18	45	90	72	60	48	42	36
19	47½	95	76	63⅓	50⅔	44⅛	38
20	50	100	80	66⅔	53⅓	46⅜	40

THREE-COLUMN RADIATOR FOR STEAM OR HOT WATER HEATING.

Number of Sections.	Length in Inches.	SQUARE FEET OF HEATING SURFACE.			
		39 Inches High.	33 Inches. High.	27 Inches High.	21 Inches High.
2	5	12	10 1-2	8 1-2	6 1-2
3	7 1-2	18	15 3-4	12 3-4	9 3-4
4	10	24	21	17	13
5	12 1-2	30	26 1-4	21 1-4	16 1-4
6	15	36	31 1-2	25 1-2	19 1-2
7	17 1-2	42	36 3-4	29 3-8	22 3-4
8	20	48	42	34	26
9	22 1-2	54	47 1-4	38 1-4	29 1-4
10	25	60	52 1-2	42 1-2	32 1-2
11	27 1-2	66	57 3-4	46 3-4	35 3-4
12	30	72	63	51	39
13	32 1-2	78	68 1-4	55 1-4	42 1-4
14	35	84	73 1-2	59 1-2	45 1-2
15	37 1-2	90	78 3-4	63 3-4	48 3-4
16	40	96	84	68	52
17	42 1-2	102	89 1-4	72 1-4	55 1-4
18	45	108	94 1-2	76 1-2	58 1-2
19	47 1-2	114	99 3-4	80 3-4	61 3-4
20	50	120	105	85	65

FOUR-COLUMN RADIATOR FOR STEAM OR HOT WATER HEATING.

Number of Sections.	Length in Inches.	SQUARE FEET OF HEATING SURFACE.				
		42 1-2 Inches High.	38 1-2 Inches High.	32 1-2 Inches High.	26 1-2 Inches High.	20 1-2 Inches High.
2	8 1-2	19 1-3	16	13 1-3	10 2-3	8
3	12 1-2	29	24	20	16	12
4	16 1-2	38 2-3	32	26 2-3	21 1-3	16
5	20 3-4	48 1-3	40	33 1-3	26 2-3	20
6	24 3-4	58	48	40	32	24
7	28 3-4	67 3-3	56	46 2-3	37 1-3	28
8	32 3-4	77 1-3	64	53 1-3	42 2-3	32
9	37	87	72	60	48	36
10	41	96 2-3	80	66 2-3	53 1-3	40
11	45	106 1-3	88	73 1-3	58 2-3	44
12	49	116	96	80	64	48
13	53	125 2-3	104	86 2-3	69 1-3	52
14	57 1-2	135 1-3	112	93 1-3	74 2-3	56
15	61 1-2	145	120	100	80	60
16	65 1-2	154 2-3	128	106 2-3	85 1-3	64
17	69 1-2	164 1-3	136	113 1-3	90 2-3	68
18	73 3-4	172	144	120	96	72
19	77 3-4	183 2-3	152	126 2-3	101 1-3	76
20	82	193 1-3	160	133 1-3	106 2-3	80

Radiator Connections. Methods of connecting radiators used in steam heating plants are shown in Figs. 26 and 27.

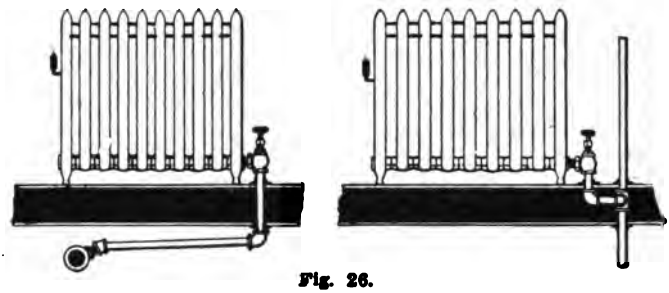


Fig. 26.

They should be made in such a manner as to allow for expansion and contraction in the branch

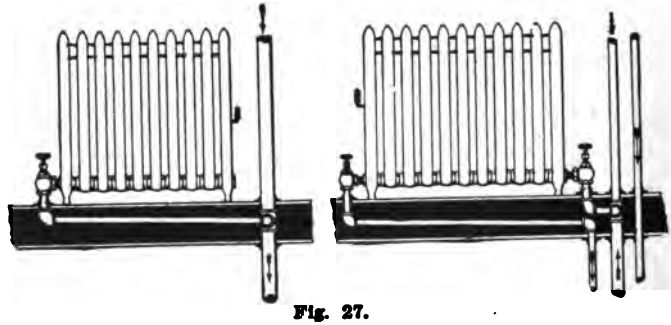


Fig. 27.

supply to the radiator. This provision is shown in the illustrations of radiator connections shown in Figs. 26 and 27.

When the overhead system is used, the radiators may be fed at the top of one end, and the return taken out of the bottom of the same or opposite end.

The circulation of water in either case is positive.

All radiator connections should be of sufficient area to give the best results.

Pipe Tap for Radiator Connections

ONE PIPE SYSTEM	
Square Feet of Radiation	Size of Pipe Tap in Inches
20	1
25 to 50	1¼
50 to 75	1½
75 to 100	2
TWO PIPE SYSTEM—TWO TAPPINGS	
20	¾ x ¾
25 to 50	1 x ¾
50 to 75	1¼ x 1
75 to 150	1½ x 1¼

Air Valves. Automatic air valves have almost entirely superseded the use of hand operated air cocks. They are made with a composition disc, which is arranged to close the valve as soon as the hot steam comes in contact with it. They are pro-

vided with a screw attachment by which the valve opening can be adjusted after the valves are in place. The only disadvantage of the automatic air valve is that when steam is turned on, the entire radiator becomes heated. By means of the plain air cock the amount of the radiator heated can be regulated, especially when connected on a one-pipe system. The automatic air valve takes the circulation in the radiator entirely out of the hands of persons who are not acquainted with their principles, and in the case of indirect radiators is an absolute necessity.

Fig. 28.

Fig. 28 shows three forms of automatic air valves, and Figs. 29 and 30 four styles of hand operated air cocks.

Valves. Straightaway valves, commonly called quick-opening radiator valves, are best adapted to this work. Only one valve is used on a hot water radiator which is located in the supply pipe, as close to the radiator as possible. One valve is

used on a one-pipe steam system, and two on the two-pipe system. Valves should be used which have removable discs, such as the Jenkins disc valve. On one-pipe work the radiator valve should be placed on the flow pipe, and on two-pipe work on both flow and return pipes. To shut off a steam radiator the valve on the return should be closed

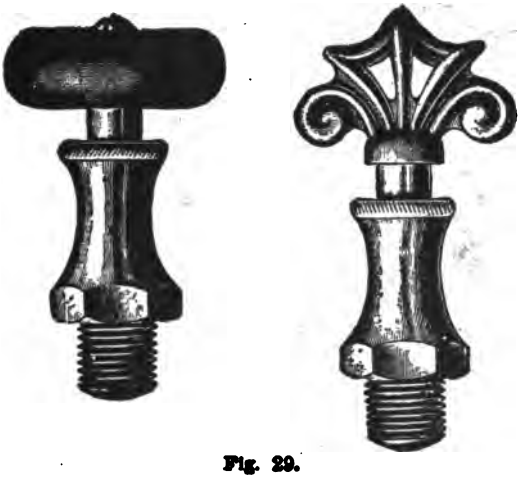


Fig. 29.

first, the supply valve last, and in all cases both valves should be entirely closed or entirely open. To turn on a steam radiator the supply valve should be opened first, then the valve on the return. The valves should be connected to close against the steam pressure, in order that the stuffing boxes may be packed or repacked while the

heating system is in operation. Gate valves should be used in the mains and risers for the reason that they have a full opening and do not impede the circulation.

Radiator Valves. The most commonly used form of radiator valve is the angle valve, with or without union connection, and with composition

Fig. 30.

disc, wood wheel, rough body and nickel trimmings, as shown in Figs. 31 and 32.

Gate valves as shown in Fig. 33 are sometimes used when the radiator connections require them, especially on a down or overhead system of piping.

Angle valves with lock and shield as illustrated in Fig. 34 are much used in public buildings.

Globe valves if used in a steam heating system restrict the flow of both steam and condensed water. Their use should be avoided if possible.

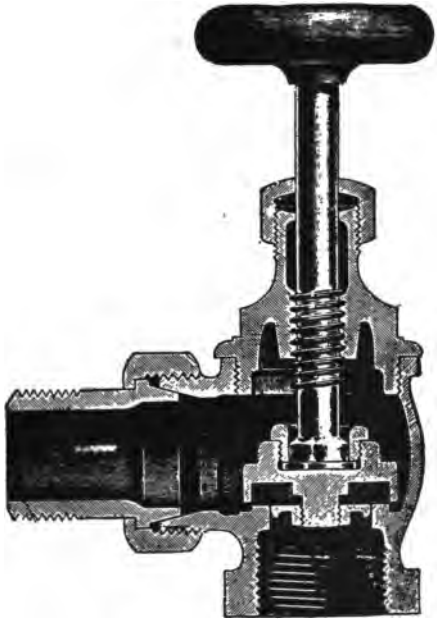


Fig. 31.

Figs. 35 and 36 show vertical cross-section and outside views of a globe valve.

Swing check valves should only be used on the main section of a two-pipe system, close to the boiler, or when the return is underground, to pre-

vent the boiler from being emptied from a leak or break in the return pipe.

An outside view and a vertical cross-section of a swing-check valve are shown in Fig. 37.

Corner radiator valves are generally used when

Fig. 32.

the radiator connections are above the floor line. Right and left-hand corner valves are shown in Fig. 38.

A brass plug-cock with square or flat head, as shown in Fig. 39, for blowing off the boiler, should always be installed either in the return pipe near

the boiler or in the boiler itself. It should not be directly connected with a pipe to the sewer, the end of the pipe should be in plain sight, so that

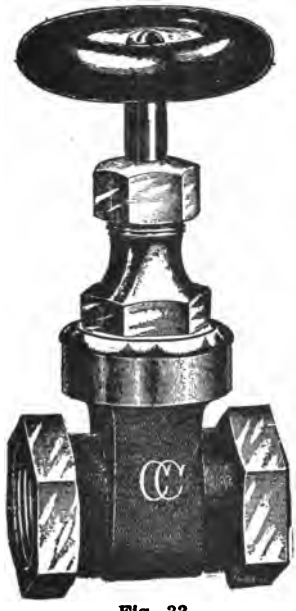


Fig. 33.

any leakage due to not closing the cock properly may be noticed.

Unsteady Water Line in Boiler. This trouble often results from grease in the boiler, the grease usually being present by reason of its use in the

construction of the piping and manufacture of the boiler and radiators. The grease rests on the sur-

Fig. 34.

face of the water in the boiler, forming a scum, and when this occurs, the bubbles of air formed by the boiling water cannot reach the surface of the water

and burst off into steam. This causes a disturbance in the boiler, the bubbles seeking for an outlet naturally finding it in the connection to the water column, or gathering in such force under a

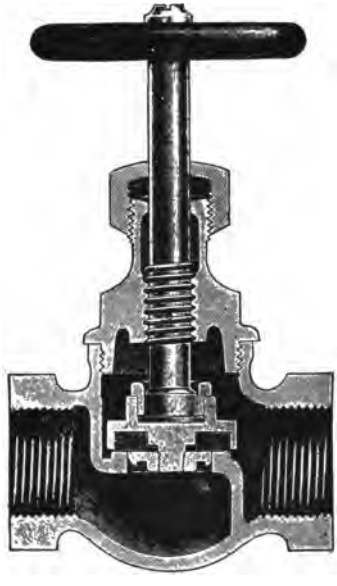


Fig. 35.

portion of the scum, that they break together, and with such force as to force water into the steam main, often causing a vacuum which will empty the water glass and water column connections entirely.

Blow the boiler off under pressure. This will usually remove most of the grease, if the unsteady line is due to grease. It may be necessary to repeat

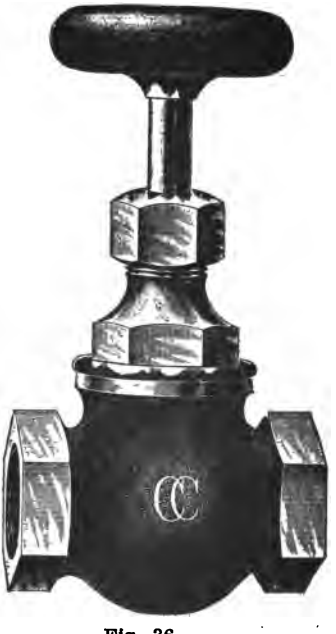


Fig. 36.

this operation several times, at intervals of a few days, before the boiler is entirely clean. If the cause be due to the construction of the boiler, it may be necessary to use an equalizing pipe, that is, to make a direct connection from an opening in

the top of the boiler to a return opening in the bottom of the boiler.

Starting a Steam Heating Plant. After all the connections are made, pack the radiator valves and attach the air valves. Fill the boiler to the water line and start the fire, allowing the entire system to fill with steam by opening all the valves. When the steam has blown freely out of all air valves,

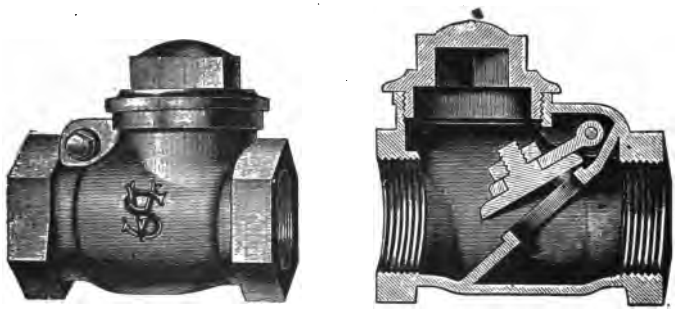


Fig. 37.

close the same, and if they are automatic adjust and regulate them, which may have to be repeated a number of times before they are in good working order. Carry the pressure of steam high enough so that the safety valve will blow off from 5 to 10 pounds. Inspect every portion of the system carefully, and if any leaks are found note the same and when the steam is down make the necessary re-

pairs. After the system is found tight, keep the boiler under fire several days, and then blow it off according to the following directions:

Close the main steam and return valves, or all

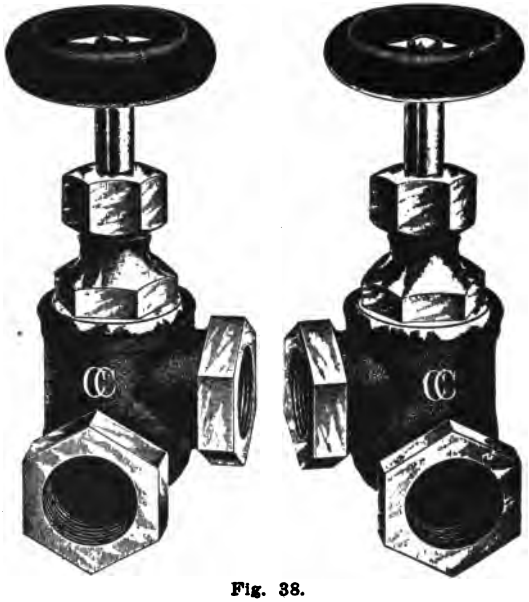


Fig. 38.

radiator valves. Make a good fire and get up a pressure of at least ten pounds. Open the blow-off valve, being careful that just enough fire is carried to maintain a pressure until the last gallon of water is blown out. Allow the fire to go out. Open

the fire and flue doors, and in about half an hour, close the blow-off valve, and refill boiler slowly to the water line, then open all radiator and main valves, and start the fire.

The boiler should be blown off within a week after it is installed and in operation.

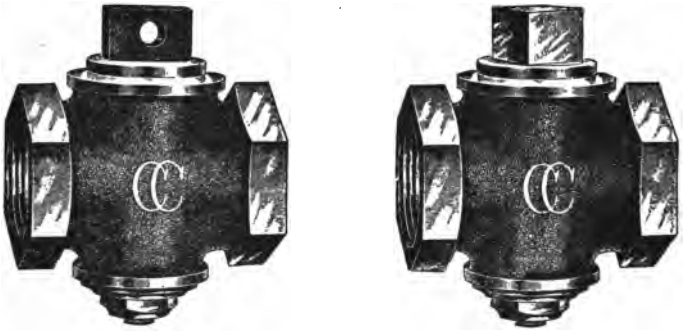


Fig. 39.

Steam Heating Plant. Figs. 40, 41 and 42 show the plans for a three-story and basement apartment building equipped with a one-pipe return system. The boiler, steam mains, piping to radiators and radiators are all plainly shown.

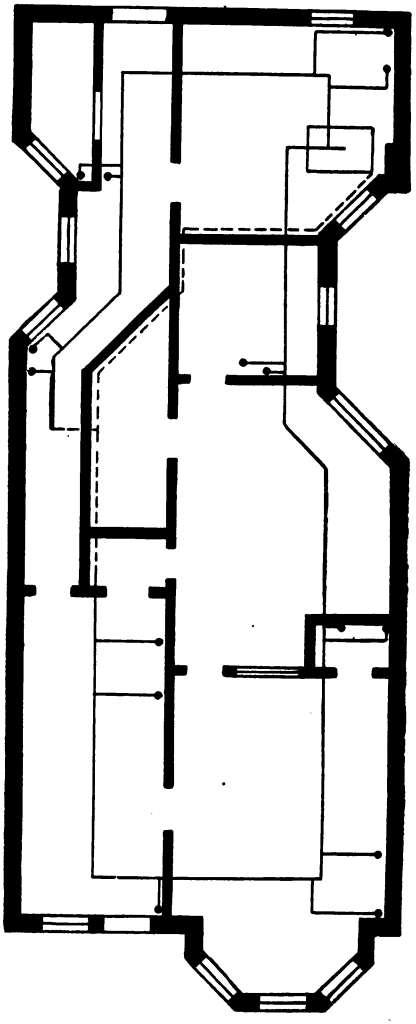


Fig. 40. Basement.

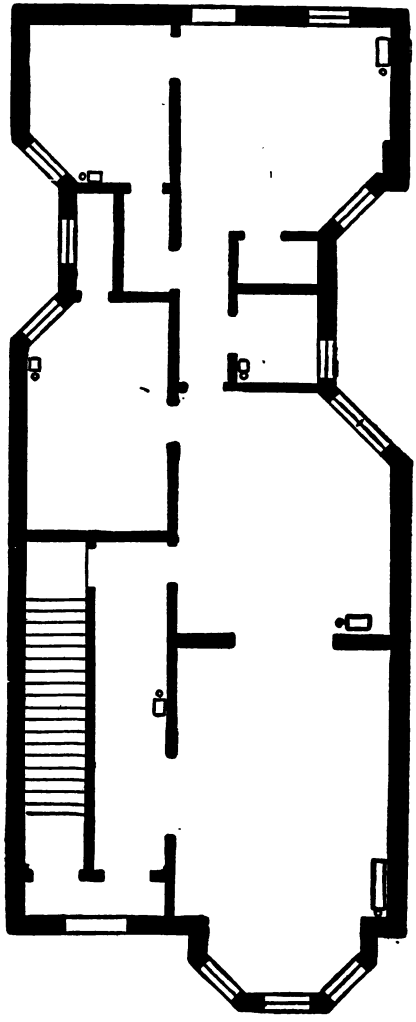


Fig. 41. First Story.

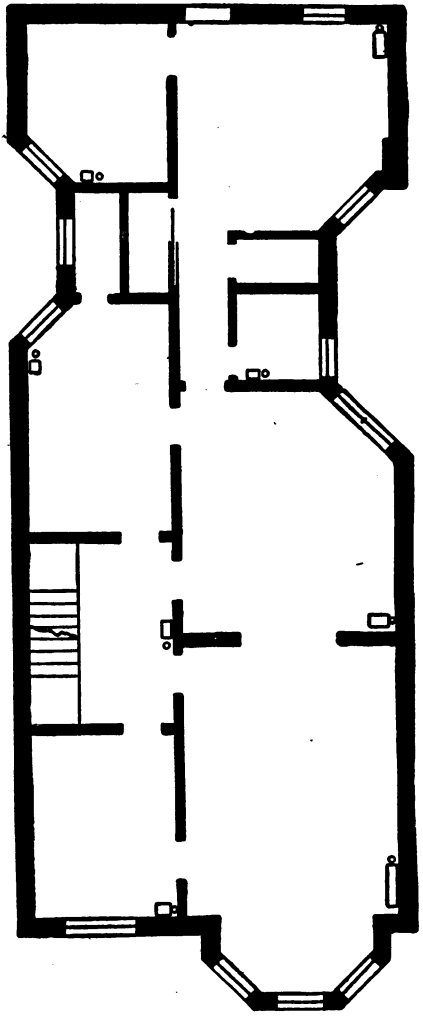


Fig. 42. Second and Third Story.

TEMPERATURE OF STEAM AT VARYING PRESSURES, IN DEGREES FAHRENHEIT.

Gauge Pressure.	Absolute Pressure.	Temperature in Degs. Fahrenheit.
0	15	212
5	20	228
10	25	240
15	30	250
20	35	259
25	40	267
30	45	274
35	50	281
40	55	287
45	60	292
50	65	298
55	70	302
60	75	307
65	80	312
70	85	316
75	90	320
80	95	324
85	100	327
90	105	331
95	110	334
100	115	338
110	125	344
120	135	350
130	145	355
140	155	361
150	165	366

Estimating. Make a careful survey of the location, construction and exposure of the building to be heated, and take accurate measurements of the size of the glass surface and exposed walls of the rooms in which the radiators are to be placed.

Having ascertained the total amount of radiation, select a boiler having a rated capacity of 50 per cent in excess of the total radiation, which for the average system will allow for the duty imposed by the mains and provide a margin of 20 per cent.

Make a plan of the basement to scale, locate the boiler, and lay out the pipe system, putting down the size of the mains and the branches.

From the plan obtain the number of lineal feet of each size of pipe, including the risers, also the number and size of all fittings.

Allow one air valve for each radiator, and one for the end of the steam main.

The number and size of the floor and ceiling plates may be counted from the number and size of risers that will pass through the floors and the ceilings.

The length of pipe covering may be obtained from the size and number of lineal feet of pipe in the mains.

SPECIFICATION AND CONTRACT FOR A STEAM HEATING PLANT.

We hereby agree to furnish and install in your house, ... street, a Steam Heating Plant, under the conditions, and for the price hereinafter named, and in accordance with the following specifications:

Boilers. Furnish and set up in basement one No. —— steam boiler, having a rated capacity of ..... square feet, and provide same with a set of fire and cleaning tools.

Foundation. The owner is to provide a suitable brick or concrete foundation for the boiler.

Smoke Pipe. Connect the smoke collar of the boiler to the chimney flue by a ....-inch galvanized iron smoke pipe, provided with a choke damper.

Chimney. The owner is to provide a chimney flue of sufficient size and height to secure a proper draught.

Fittings. The steam main, risers and branches to the radiators to be of ample areas and properly graded and supported in basement by neat, strong hangers, secured to ceiling joists. All fittings to be of best grade cast iron, and reducing fittings to be used, not bushings.

F. & C. Plates. Where risers and radiator connections pass through floors and ceilings, protect the openings with neat bronzed or nickel-plated floor and ceiling plates.

Valves. Each radiator is to be furnished with a nickel-plated wood-wheel Disc Radiator Valve.

Air Vents. Each radiator to be provided with an automatic air valve.

HOT WATER HEATING.

The open tank, and the closed tank or pressure systems are in general use.

The open tank system is preferable to the closed tank system, as it may be more easily and safely operated.

In the open tank system a vent pipe is carried from the expansion tank through the roof or side of the building open to the atmosphere. The closed tank system is not vented, and is therefore under pressure and requires a safety valve.

In the closed tank system the water may be heated to a temperature above 212 degrees, the boiling point of the open tank system.

A safety valve should be placed on the expansion tank, with a pipe running from the open side of the valve to a sink or drain, in order that when sufficient pressure is raised to operate the valve, any overflow of water may be carried off without injury to the building.

Ten pounds is the proper pressure at which the safety valve should work on the closed tank system.

The piping for the closed tank or high pressure system may be somewhat smaller than for the open tank or low pressure system, but the piping should

be run and the connections taken off in the same manner for each system.

The mains should be pitched 1 inch for each 10 feet of length.

The mains in a hot water system should not be reduced too rapidly as branches are taken off, as the greater amount of friction in the smaller sizes of pipe will cause trouble.

Radiators may be heated by hot water on the same level as the boiler, or below it.

Under these conditions the circulation results from the weight of water above the low radiators. This depends on the fact that a column of water 2.32 feet in height will produce about 1 pound of pressure.

This may be done by carrying the flow pipe up so as to get a pressure from the weight of water above, to produce circulation.

A hot water system should be filled from the lowest point if possible, for the reason that the water will drive the air out of the system as it rises.

The air vents should all be opened to allow the air to escape, being closed as each radiator is completely filled with water.

Round Water Heaters. The heater shown in Fig. 43 is entirely of cast iron construction, so arranged as to amply provide for expansion and contraction. The only joints or connections are formed of heavy

cast iron threaded nipples, making a perfect joint, with no possibility of leaks from any cause whatsoever and absolute freedom from all

Fig. 43.

necessity of packing of any kind. The general construction of water heaters is as follows:

The circular base, or ashpit, which also forms the support for the grate, is substantially made of

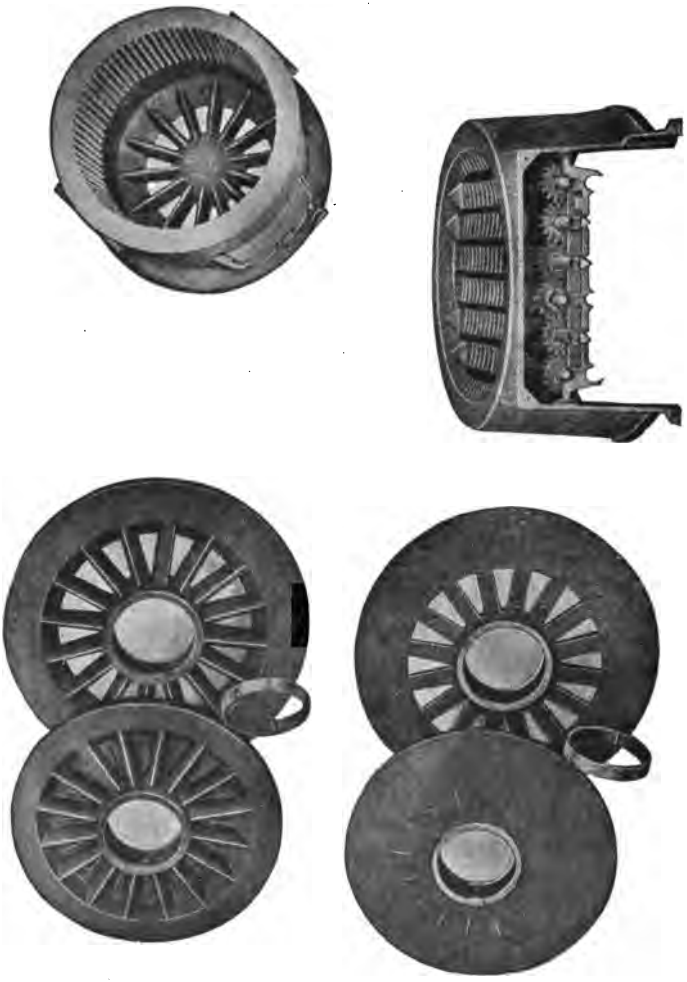


Fig. 44.

cast iron and gives a safe depth for accumulation of ashes. Resting on this is the firepot section, shown in Fig. 44. This section, being one complete casting in itself, and tested under heavy pressure before leaving the shop, is absolutely free from mechanical imperfections. In the center of the top of this section is a large opening, threaded to receive a nipple, which connects it with a closed section, shown in the right hand upper view, Fig. 44. This first, or intermediate section, is of less diameter than the top of the firepot section. On top of this closed, or intermediate section and attached to it in the same manner, as described for the connection of the firepot, there is an open section shown in the right hand upper view, Fig. 44, which is of the same diameter as the top of the firepot and entirely fills the jacket casings hereinafter described. On top of this is placed another closed section, and on top of this again comes the top section, which is either the steam dome, forming the steam boiler, or the upper water section, forming the water heater, all connected together in the manner described, with screw nipples, the top section, or dome, having the necessary tappings for the supply outlets for steam, or the flow outlets for water.

Casings. Extending from the outer edge of the top of the firepot section to the top of the upper section, or dome, there are cast iron casings, close-

ly fitted joints. These casings are made in segments and are interchangeable and easily applied, with no possibility of rusting, wearing out or breaking. They form in themselves a perfect chamber for the retention of products of combustion, compelling these to follow such channels as will give best results.

Firepot. The firepot is circular in form, entirely surrounded by water, is made in one perfect casting, and free from any possible chance of leakages. The inner surface of the firepot has projecting into it all around the sides a multiplicity of iron points, just long enough to prevent the water contract from chilling the fire and making it possible to secure perfect combustion and a uniform fire around the edges as well as in the center. The firepots are of sufficient depth to insure a deep, slow fire, forming the best and most economical heat-producing proposition for low pressure heating.

Grate. The grate is of the triangular form and is at all times easily operated, and in its operation it pulverizes all clinkers before depositing in ash pit.

On all the larger size boilers the grates are fitted with a heavy bearing bar in the center, thus prolonging the life of the grate bars, as it prevents their warping.

Simplicity of the Grates. The construction of the grate is exceedingly simple, and admits of

any one bar of the whole grate being changed without the assistance of skilled labor.

Fig. 45 shows vertical cross-section of a steam boiler.

Fig. 45.

Rectangular Sectional Heaters. The vertical sectional type of steam heaters has been on the market and in all forms for a number of years. There are no new ideas that can be safely exploit-

ed in this line. The demand is for a simple, practical, easily handled device that will absolutely endure the work appropriated for it.

The heater shown in Fig. 46 is strong, of good

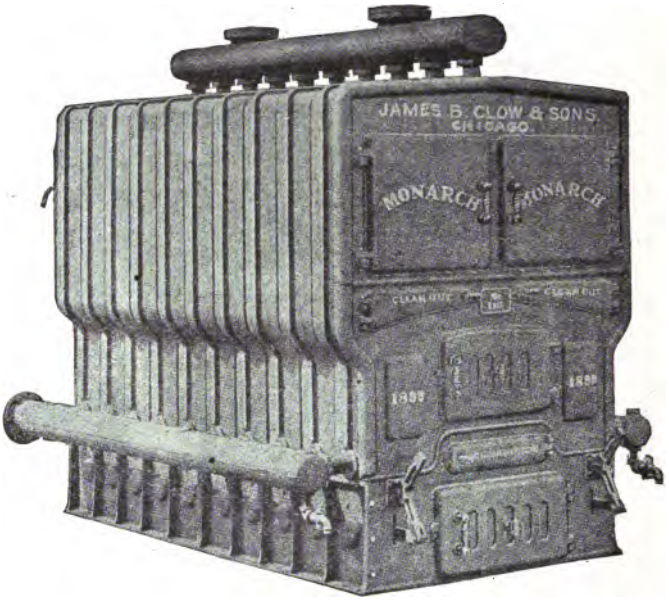


Fig. 46.

appearance, thoroughly accessible for cleaning, and, so far as can be determined from exterior appearances, a most satisfactory heater. The good opinion already formed of the heater is further

strengthened by reference to views of the intermediate and rear sections shown in Fig. 47 and 48. By reference to these cuts it will be seen that every possible advantage is taken of the fire surface, it being the belief that, unless great good is

Fig. 47.

accomplished in direct contact with the fire, there will be but little assistance obtained from the flues.

Firepots. Firepots of this type of heaters are deep, to give a compact body of fire, and, besides,

are covered with numbers of iron projections to prevent chilling contact of the fire with the exposed water surface and yet secure such perfect combustion as will quickly impart to the water the heat from the fuel and permit of maintaining at all times a clear, even fire in every portion of the firepot.

Fig. 48.

Heater Capacity. The capacity of the heater should be at least 20 per cent in excess of the total duty imposed upon it by the radiation and pipe system.

Example: Let 600 square feet equal the total radiation, plus 25 per cent for the surface of the mains, plus 20 per cent excess heater capacity, which is 900 square feet, the capacity of the boiler required. The same result may be arrived at by adding 50 per cent to the radiation.

When direct-indirect radiation is used, an additional 33 1/3 per cent must be allowed, and when indirect radiation is used, add 50 per cent.

Example:

Total direct radiation=	450	sq. ft.
One direct-indirect radiator=	60	" "
One indirect radiator=	190	" "
	600	" "
25 per cent for surface of mains=	112.5	" "
33 1/3 per cent on direct-indirect=	20	" "
50 per cent on indirect radiator=	45	" "
	777.5	" "
20 per cent excess capacity=	155.5	" "
Heater capacity	933	" "

Thermometers. A thermometer should be attached to every water heater as it not only registers the temperature of the water but it indicates to the attendant the required temperature of the water to be maintained for different conditions of the weather. It should be located in the top of the

heater or in the side near the top so that the closed brass chambers comes in direct contact with the

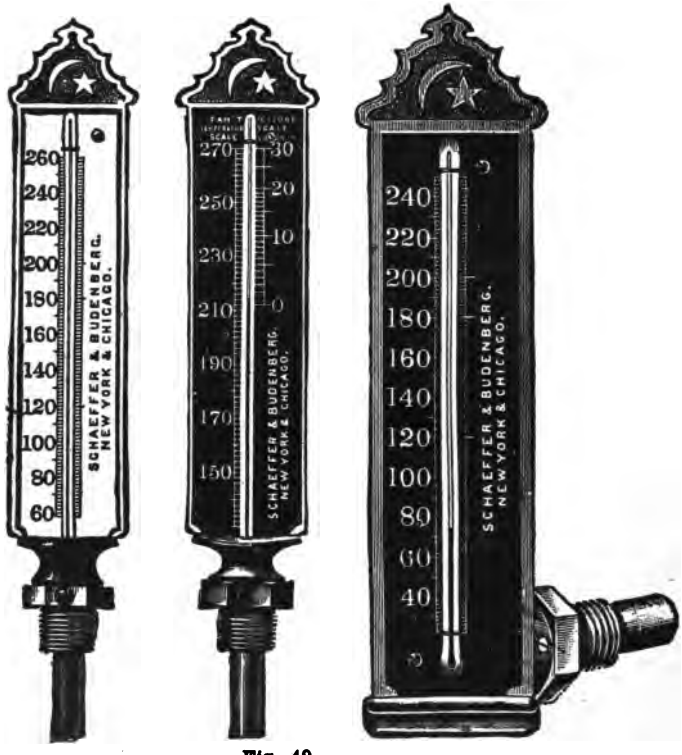


Fig. 49.

water circulation. Thermometers for use with water heaters are shown in Fig. 49.

Pipe Systems. The quadruple main hot water heating system shown in Fig. 50 when properly

installed will give very satisfactory results, and on account of the small size of the mains that are required it comes well within the range of the tool equipment of a heating contractor.

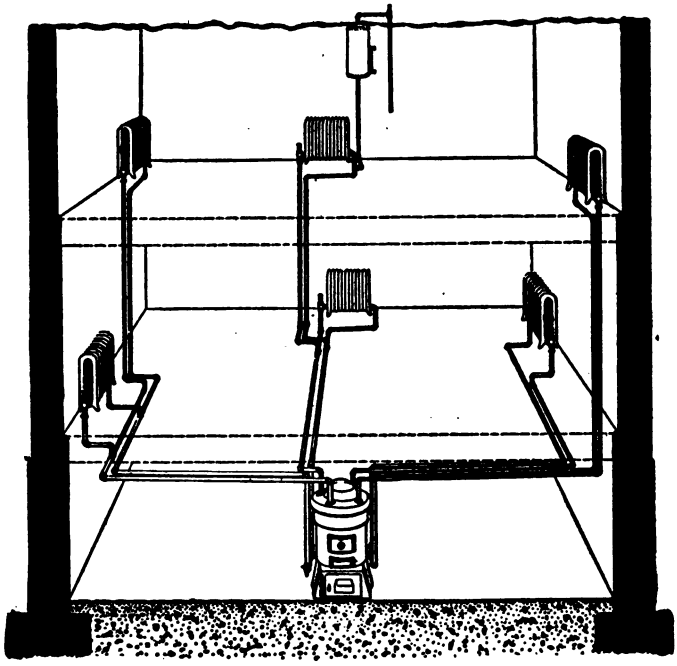


Fig. 50.

The double main system, as shown in Fig. 51, consists of flow mains starting from points on top of the boiler and running horizontally with a pitch of 1 inch or more in each 10 feet from the boiler.

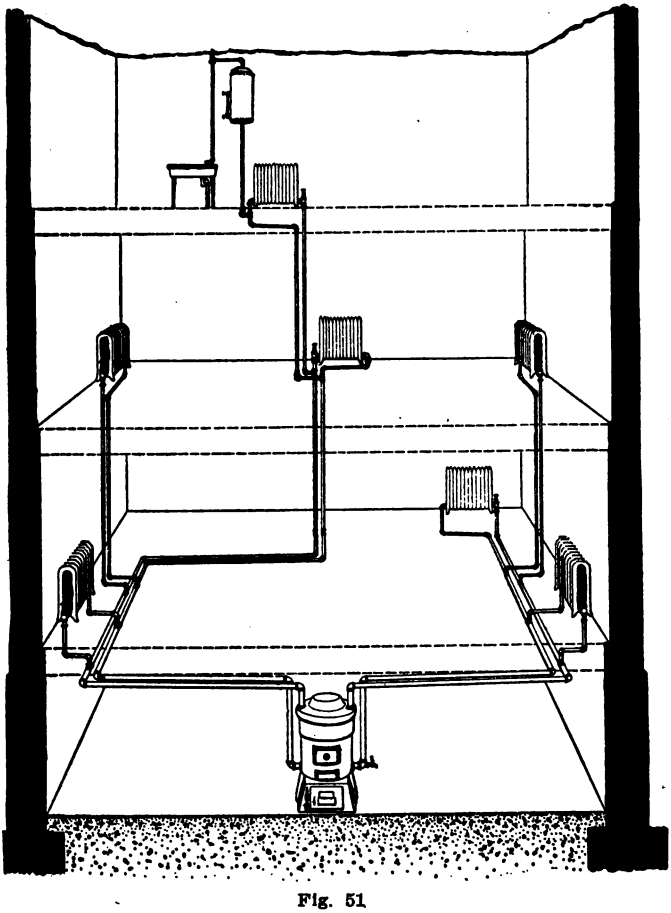


Fig. 51

This is a system that is very much used and considered by many the best practice to follow.

The single pipe overhead or down-feed system

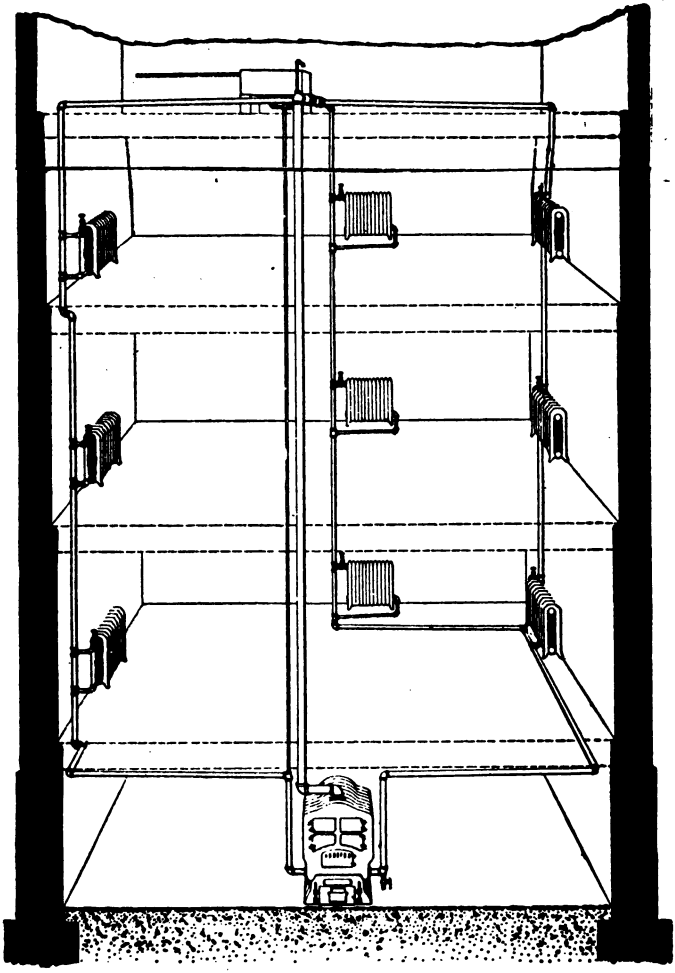


Fig. 52.

is much used in large office buildings. As illustrated in Fig. 52 a single feed or supply pipe runs from the top of the heater to a point some distance above the highest radiator. At this point the down-feed pipes branch out to the different sets of radiators. The expansion tank is connected to the system by a separate pipe at a point near the heater as shown. A vent pipe is also placed at the top of vertical supply pipe. The expansion tank should always be above the highest line of pipe.

Heating Surface. To estimate the amount of heating surface required to heat a room with hot water to a temperature of 70 degrees in zero weather, with the water at a temperature of 180 degrees at the heater and under ordinary conditions of exposure, the following rule is given, which is for direct radiation, and based upon the glass surface exposed wall surface and cubic space.

1 square foot of radiation to 1 square foot of glass.

1 square foot of radiation to 10 square feet of wall exposed.

1 square foot radiation to 150 cubic feet of spaced.

For each degree of temperature above or below zero, deduct from or add to, 1½ per cent of the radiation given by this rule.

Hot Water Mains. The proper size of mains for hot water heating are given in the accompanying table:

Proper Size of Hot Water Mains.	
Size of Main in Inches.	Sq. ft. Direct Radiation.
1½	175
2	300
2½	400
3	650
3½	900
4	1200
4½	1500
5	2000
6	2700
7	4000
8	5500

Radiator Connections. All radiator connections should be of sufficient size to give the best results.

Tapping of Direct Hot Water Radiators.	
40	1 x 1
40 to 72	1¼ x 1¼
72 to 100	1½ x 1½
100 to 150	2 x 2
Tapping of Direct Hot Water Radiators. Two Pipe—Two Tappings.	
20	¾ x ¾
20 to 40	1 x ¾
40 to 80	1¼ x 1
80 to 120	1½ x 1¼

Example: Required the number of square feet of direct radiation for a room 10x10x10 feet, having two exposed sides and two windows 2½x6 feet.

Answer:

Glass surface=	30 sq. ft.÷ 1=	30	sq. feet
Exposed walls=	200 sq. ft.÷10=	20	"
Cubic space=	1,000 cu. ft.÷10=	6.6	"
	Total direct radiation=	56.6	"

Example: Required the number of square feet of direct radiation for the same room, with one exposed side and one window 2½x6 feet.

Answer:

Glass surface=	15 sq. ft.÷ 1=	15	sq. feet
Exposed walls=	100 sq. ft.÷ 10=	6.6	"
Cubic space=	1,000 cu. ft.÷150=	6.6	"
	Total direct radiation=	31.6	"

When indirect radiation in used 75 per cent should be added to the above figures.

RADIATION.

Direct Radiation. This consists of a heating surface in the form of a radiator or coil, which is placed directly in the room to be heated.

Indirect Radiation. Radiators in the room to be heated on the first or second floor are located in the cellar or basement, usually directly under the rooms to be heated. There is placed in the floor of the room to be heated, or in the side wall above the baseboard, a register and connection is made between this register and the radiator in the basement by means of tin or sheet iron pipe, for conveying the heated air into the room.

The indirect radiator is placed in a chamber into which fresh air is conveyed from outside, and to which the hot air flue to the register is connected.

The distance from the top of the radiator to the ceiling of the casing should be from 10 to 12 inches and from the bottom of the radiator to the bottom of the casing from 6 to 8 inches. The dimensions of the cold air inlet should be 1½ square inches for each square foot of indirect radiation. The warm air outlet should be 2 square inches for each square foot of indirect radiation, which would be for a radiator containing 100 square feet of

radiation, 200 square inches of cross sectional area, or a duct 10x20 inches. The dimensions of the warm air register should be 50 per cent larger than those of the warm air duct, which allows for the contracted area caused by the register face. A warm air duct having 200 square inches of cross sectional area should have a register approximating 300 square inches.

Direct-Indirect Radiation. This system serves a double purpose, that of Direct Radiation and Ventilation, and is also placed in the room to be heated under windows, or close to the exposed walls.

The lower front part of the radiator is encased, having an opening at the bottom or back of the base for the introduction of cold air by means of a duct through the outside wall of the building.

On account of the cooling effect of the outside air passage between the coils of the radiator, increased heating surface to the amount of 33 1/3 per cent must be added to make it equivalent to direct radiation.

This system of radiation is seldom used in the heating of houses, being more necessary where ventilation is required in the heating of public buildings and schools.

Instead of placing all of the radiators at one point, it is well to divide it into two or more radiators, according to the size of the room. As heating with steam or hot water is accomplished by the

turning or circulation of the air in the room, it is well to divide and place the radiation at the most exposed points, in order to better heat the room.

In small houses a radiator placed in the lower hall, if sufficiently large, will heat the hall above, but in large buildings, where the hall space is large, the upper halls should have radiators placed in them.

Radiators. Heating surfaces are divided into three classes: Direct radiation, Indirect radiation and Direct-indirect radiation.

Direct radiation covers all radiators placed within a room or building to warm the air, and are not connected with a system of ventilation.

The best place within a room to place a single radiator, is where the air is cooled, before or under the windows, or on the outside walls. When the radiator is of vertical tube, or a short coil, which can occupy only the space under one window, and when, as often occurs, there are three windows, the riser should be so placed as to bring the line of radiators in front of, and under the windows where they will do the most good. When a small extra cost is not considered, to use two radiators and place one in front of each of the extreme windows.

When the room is large and has many windows, the heating surface, when composed of radiators, should be divided into as many units as possible.

Indirect radiation embraces all heating surfaces

placed outside the rooms to be heated, and can only be used in connection with some system of ventilation.

Fig. 53.

All the heating surface is placed in a chamber, and the warmed air distributed through air ducts.

Figs. 53, 54 and 55 show two, three and four

Fig. 54.

column forms of direct radiators, and Fig. 56 a two-piece hall or window direct radiator.

The indirect radiator is usually boxed, either in wood lined with tin, or in galvanized iron. The

Fig. 55

former is best when the basement is to be kept cool, as there is a greater loss by radiation through metal cases, otherwise the sheet metal is the best, as it will not crack.

Indirect radiators are usually hung from the

ceiling in the basement under the rooms they are intended to heat. A cold air duct is carried from

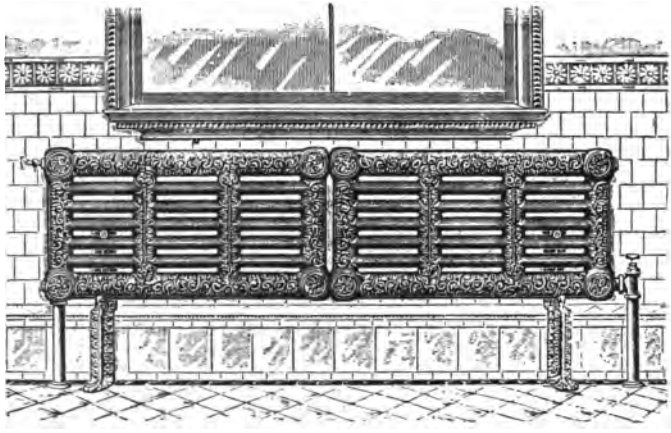


Fig. 56.

an opening in the outside wall to the stack box. This duct must be provided with a damper, and its

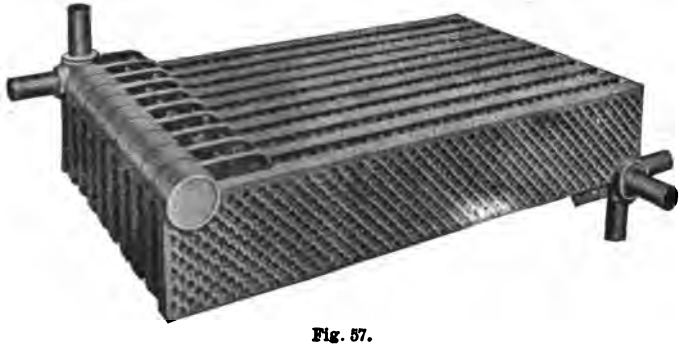


Fig. 57.

inlet covered on the face of the outside of the wall with a wire screen of small mesh.

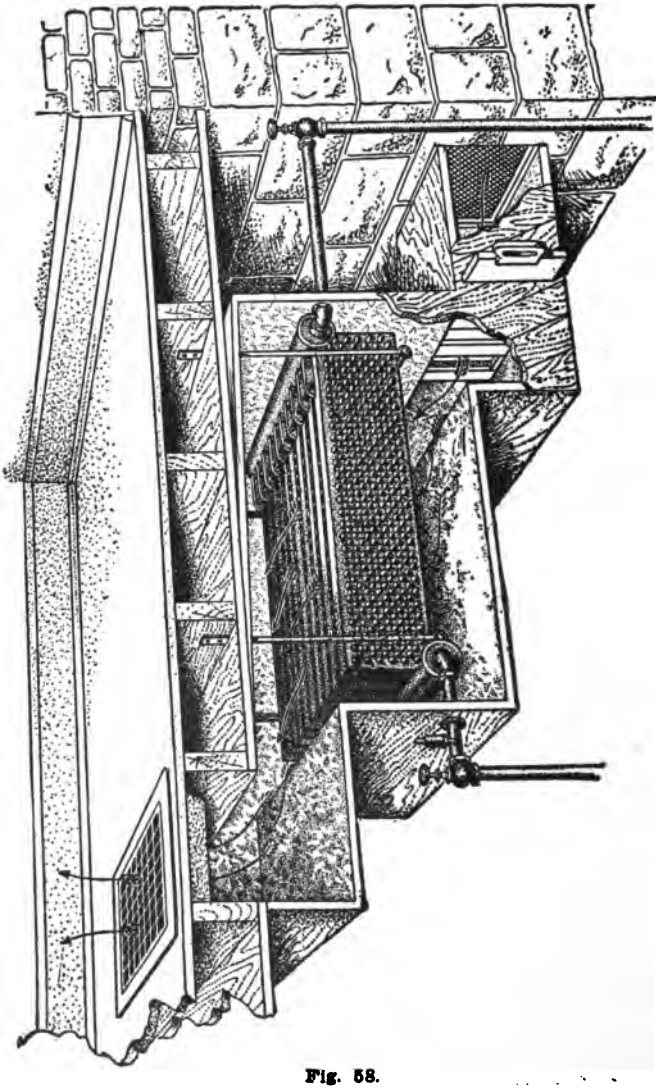


Fig. 58.

The box inclosing the radiator shown in Figs. 57 and 58 is made of wood lined with bright tin about half-way down. The sides of the box should almost touch the hubs of the radiator on both ends,

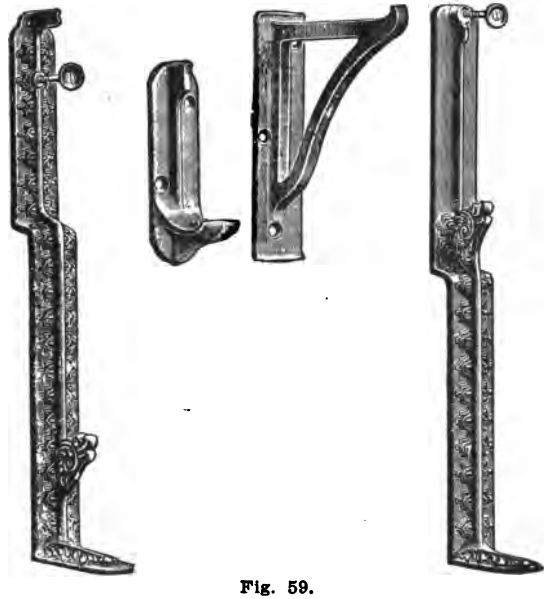


Fig. 59.

so that the cold air coming in through the duct will surely find its way up between the sections of the radiator, and not around the ends of it.

The radiator is shown connected for a two-pipe hot water system.

The cold air duct is provided with a slide, so that the air may be shut off when it is not wanted,

or when the radiator is turned off. The radiator should be so hung in the box that the space above it is about one-third more than the space below; this provides for the expansion of the air after it has been warmed by contact with the radiator.

Brackets for supporting the hall or window types of direct radiator are shown in Fig. 59.

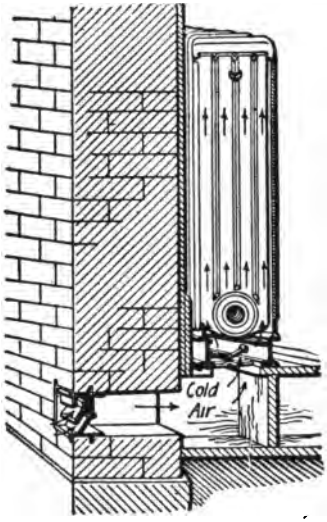


Fig. 60.

A direct-indirect form of radiator is illustrated in Fig. 60, in which the air is taken from the outside of the room to be heated and passes up between the sections of the radiator as shown, the front of the radiator being encased.

TWO COLUMN RADIATOR FOR STEAM OR HOT WATER HEATING.

No. of Sections.	Length in Inches.	SQUARE FEET OF HEATING SURFACE.					
		45 Inches High.	38 Inches High.	32 Inches High.	26 Inches High.	23 Inches High.	20 Inches High.
2	5	10	8	6⅔	5⅓	4⅔	4
3	7½	15	12	10	8	7	6
4	10	20	16	13⅓	10⅔	9⅓	8
5	12½	25	20	16⅔	13⅓	11⅔	10
6	15	30	24	20	16	14	12
7	17½	35	28	23⅓	18⅔	16⅓	14
8	20	40	32	26⅔	21⅓	18⅔	16
9	22½	45	36	30	24	21	18
10	25	50	40	33⅓	26⅔	23⅓	20
11	27½	55	44	36⅔	29⅓	25⅔	22
12	30	60	48	40	32	28	24
13	32½	65	52	43⅓	34⅔	30⅓	26
14	35	70	56	46⅔	37⅓	32⅔	28
15	37½	75	60	50	40	35	30
16	40	80	64	53⅓	42⅔	37⅓	32
17	42½	85	68	56⅔	45⅓	39⅔	34
18	45	90	72	60	48	42	36
19	47½	95	76	63⅓	50⅔	44⅓	38
20	50	100	80	66⅔	53⅓	46⅔	40

THREE-COLUMN RADIATOR FOR STEAM OR HOT WATER HEATING.

Number of Sections.	Length in Inches.	SQUARE FEET OF HEATING SURFACE.			
		39 Inches High.	33 Inches. High.	27 Inches High.	21 Inches High.
2	5	12	10 1-2	8 1-2	6 1-2
3	7 1-2	18	15 3-4	12 3-4	9 3-4
4	10	24	21	17	13
5	12 1-2	30	26 1-4	21 1-4	16 1-4
6	15	36	31 1-2	25 1-2	19 1-2
7	17 1-2	42	36 3-4	29 3-8	22 3-4
8	20	48	42	34	26
9	22 1-2	54	47 1-4	38 1-4	29 1-4
10	25	60	52 1-2	42 1-2	32 1-2
11	27 1-2	66	57 3-4	46 3-4	35 3-4
12	30	72	63	51	39
13	32 1-2	78	68 1-4	55 1-4	42 1-4
14	35	84	73 1-2	59 1-2	45 1-2
15	37 1-2	90	78 3-4	63 3-4	48 3-4
16	40	96	84	68	52
17	42 1-2	102	89 1-4	72 1-4	55 1-4
18	45	108	94 1-2	76 1-2	58 1-2
19	47 1-2	114	99 3-4	80 3-4	61 3-4
20	50	120	105	85	65

FOUR-COLUMN RADIATOR FOR STEAM OR HOT WATER HEATING.

Number of Sections.	Length in Inches.	SQUARE FEET OF HEATING SURFACE.				
		42 1-2 Inches High.	38 1-2 Inches High.	32 1-2 Inches High.	26 1-2 Inches High.	20 1-2 Inches High.
2	8 1-2	19 1-3	16	13 1-3	10 2-3	8
3	12 1-2	29	24	20	16	12
4	16 1-2	38 2-3	32	26 2-3	21 1-3	16
5	20 3-4	48 1-3	40	33 1-3	26 2-3	20
6	24 3-4	58	48	40	32	24
7	28 3-4	67 3-3	56	46 2-3	37 1-3	28
8	32 3-4	77 1-3	64	53 1-3	42 2-3	32
9	37	87	72	60	48	36
10	41	96 2-3	80	66 2-3	53 1-3	40
11	45	106 1-3	88	73 1-3	58 2-3	44
12	49	116	96	80	64	48
13	53	125 2-3	104	86 2-3	69 1-3	52
14	57 1-2	135 1-3	112	93 1-3	74 2-3	56
15	61 1-2	145	120	100	80	60
16	65 1-2	154 2-3	128	106 2-3	85 1-3	64
17	69 1-2	164 1-3	136	113 1-3	90 2-3	68
18	73 3-4	172	144	120	96	72
19	77 3-4	183 2-3	152	126 2-3	101 1-3	76
20	82	193 1-3	160	133 1-3	106 2-3	80

Radiator Connections. Methods of connecting radiators used in water heating plants are shown in Fig. 61.

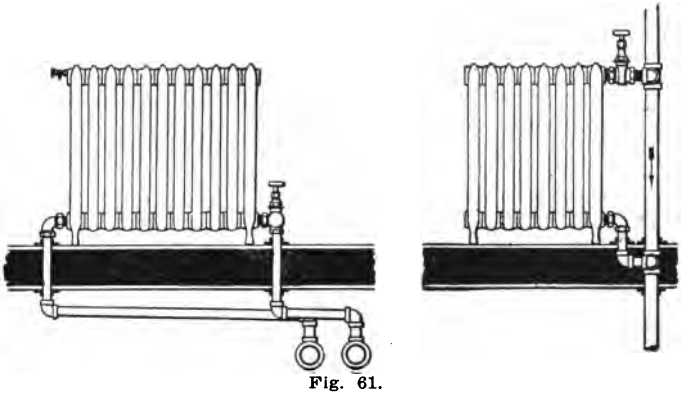


Fig. 61.

Radiator Valves. For use with hot water heating systems, angle radiator valves that have a full opening for a half turn of the wheel are usually employed. They have wood wheel, union connection and nickel-plated trimmings. This style of valve is illustrated in Figs. 62 and 63.

Angle valves with or without union connection, with wood wheel and nickel-plated trimmings, of the disk seat type are also used. They are shown in Figs. 64 and 65.

Gate valves as shown in Figs. 66 and 67 are used with down feed or overhead systems or when the radiator connections are made above the floor.

Globe valves as shown in Fig. 68 should not, if possible, to do without, be used in hot water heating systems, as their use interferes with the free circulation of the water.

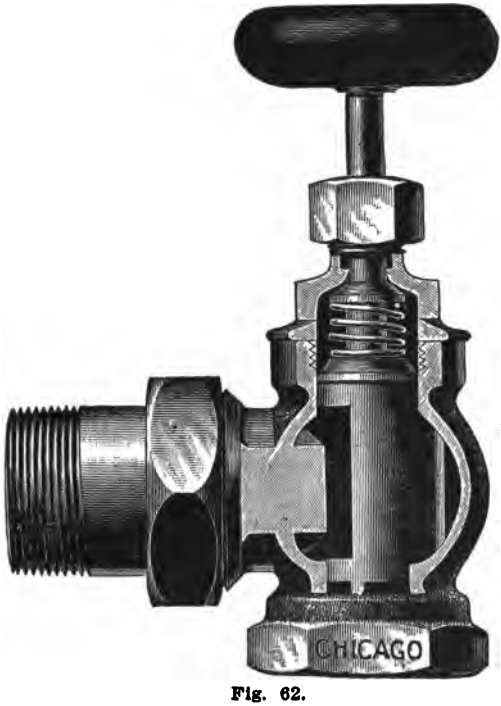


Fig. 62.

A corner valve for use when the radiator connections are above the floor is shown in Fig. 69; they are made both right and left-hand and with union connection.

A square or flat plug-cock should be always placed in the return pipe close to the boiler or in the boiler itself, as close to the bottom as possible.

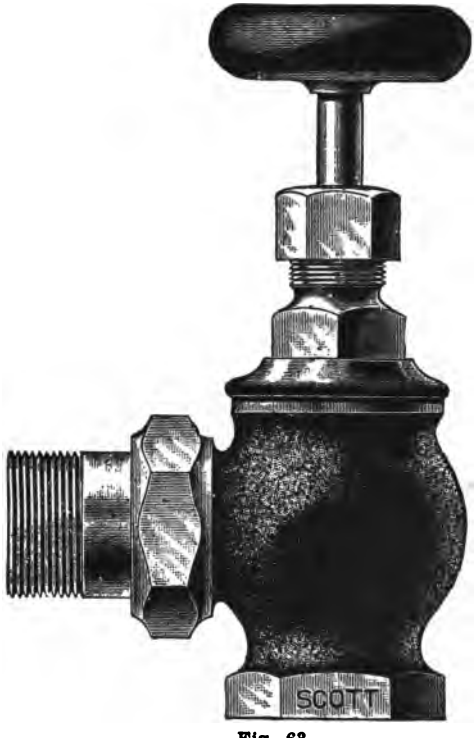


Fig. 63.

It should not have any direct connection to the sewer, but the discharge end of the pipe should be in plain sight so that any leakage due to negli-

gence in closing the cock may be quickly seen. Fig. 70 shows both square and flat-head plug-cocks.

The union-elbow shown in Fig. 71 is used to

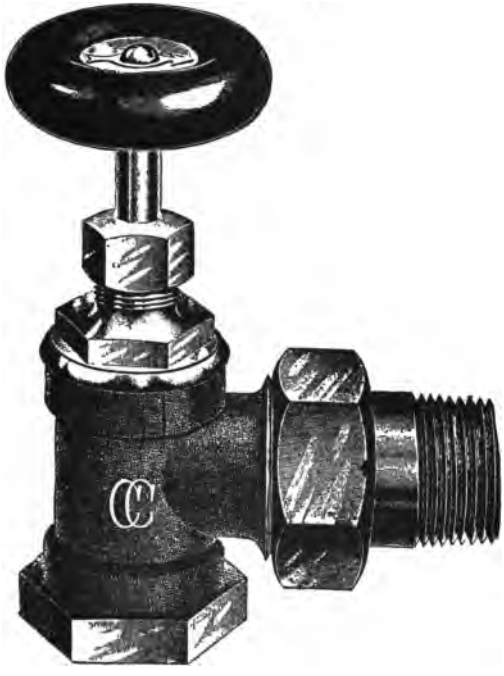


Fig. 64.

make the return connection from the radiation to the main. Check valves such as shown in Fig. 72 are sometimes used in the return main of a hot water heating system.

Check Valve. It is well understood that the common check valve is a very poor article when it is put to constant work, as it soon becomes pound-

Fig. 65.

ed out of the seat, thereby leaking. It also wears oblong in consequence of the back pressure coming against the side of the feather, which back pressure prevents the valve from closing promptly,

thereby permitting considerable water to return to the pump.

The common valves are very much choked by

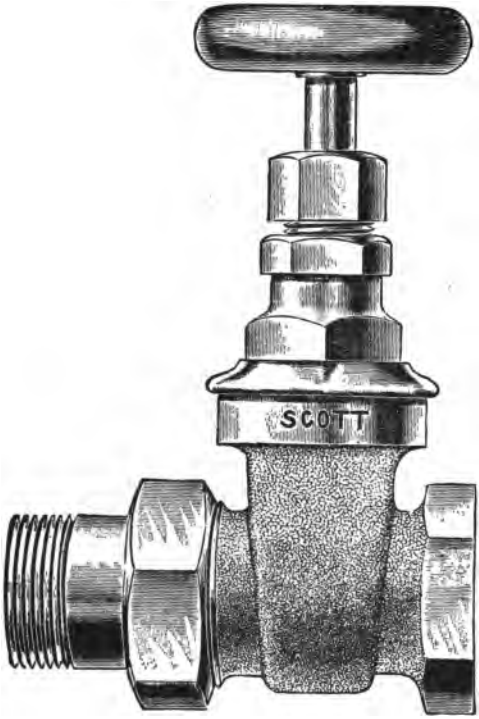


Fig. 66.

the guides, so that not more than two-thirds of their area is serviceable.

The cup pattern valve shown in Fig. 72 has a

much larger seat, a larger area, and is so constructed that the back pressure comes on the top of valve, thus preventing the side wear of the seat, and insuring prompt closing.

Fig. 67.

Expansion Tank. The purpose of an expansion tank is to provide for the increased bulk of the water in a hot water heating system, as water ex-

pands about one-twentieth of its bulk from 40 to 212 degrees Fahrenheit or to the boiling point of water. The expansion tank should always be

Fig. 68.

placed at the highest point of the system and near the ceiling at least 3 or 4 feet above the highest radiator or even higher if possible.

The expansion tank should not require more than one or two gallons per month to replenish the loss by evaporation. The overflow or vapor

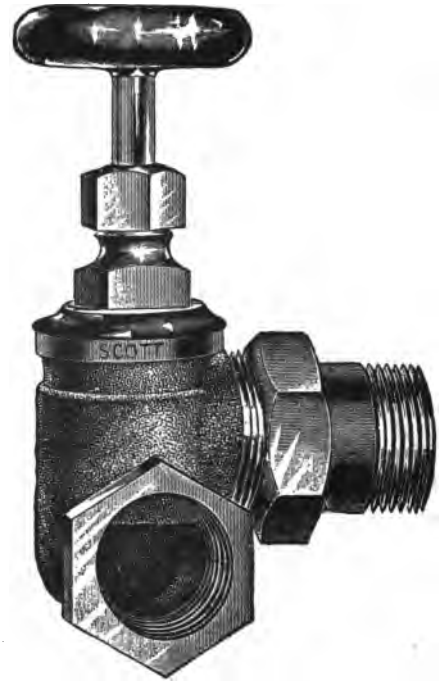


Fig. 69.

pipe should be carried to the nearest drain. The expansion tank should never be placed in an extremely cold place or an unheated room if possible. A stop-cock or globe-valve should never be placed in the pipe leading to the expansion tank.

The expansion tank should be located in a warm room, to prevent freezing.

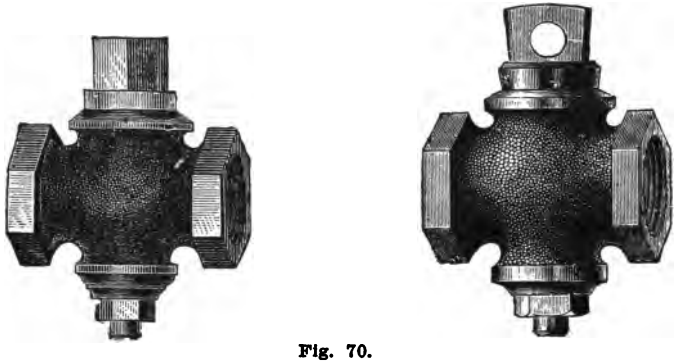


Fig. 70.

The overflow from the expansion tank should be carried through the roof, and on the end of the

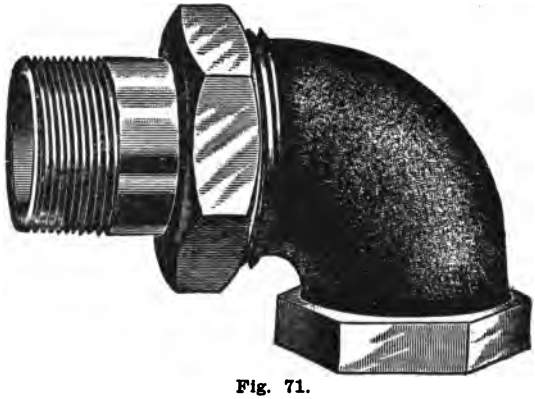


Fig. 71.

pipe a return bend should be placed, in order that the water may not run down the side of the pipe.

The expansion tank should hold from 1-20 to

1-30 of the amount of water contained in the entire system.

For the reason that when at the boiling point, the water in the system will occupy a considerably larger space than when cold.

At its boiling point, water fills a space about 5

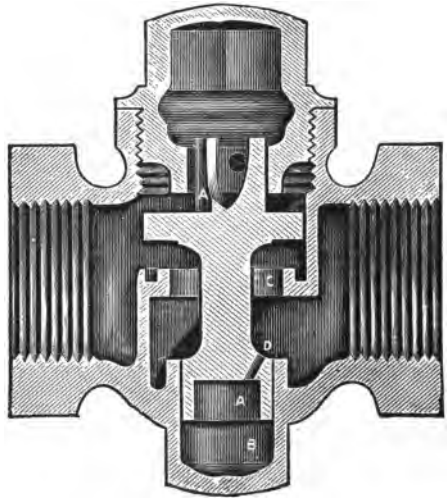


Fig. 72..

per cent. greater in volume than at its densest point, when cold. When cold, the water must fill the entire system. Therefore provision must be made to take care of this extra volume when the water is at the boiling point.

The expansion tank is provided for this purpose on all hot water heating systems.

When a wooden lead-lined tank is used and the water supply can be obtained from the city water main, a float device replenishes the water automatically.

Fig. 73.

If there be no water pressure available the tank must be filled by hand through a funnel.

A galvanized steel expansion tank is shown in Fig. 73. The overflow pipe, vent and water supply openings are all clearly shown.

Fig. 74.

A water gauge for use on an expansion tank is illustrated in Fig. 74.

CAPACITY OF EXPANSION TANKS.

No.	Diam. in Inches.	Capacity Gallons.	Sq. Ft. of Radiation.	No.	Diam. in Inches.	Capacity Gallons.	Sq. Ft. of Radiation.
0	16	8	250	5	31	32	1,300
1	17½	10	300	6	32	42	2,000
2	20	15	500	7	37	66	3,000
3	23	20	700	8	39	82	5,000
4	25	26	950	9	40	100	6,000

Altitude Gauge. The gauge shown in Fig. 75 denotes the height of a column of water in a reser-

Fig. 75.

voir or tank used in connection with heating or wherever it is desired.

The adjustable hand indicates the number of

feet in height at which the water should be constant in the reservoir, and is so set by the user when the gage is put up.

The hand operated by the gauge tube spring, which the pressure of the column of water actuates, shows in graduations on the dial marked in feet the actual height of water in the tank or reservior and consequently the fluctuations in the height of water due to its use, and thus enables the user instantly to know whether the water column is of the required and proper height to be maintained. It is of great service and usefulness in this respect.

The gauge has two dials, the red one being moveable only by hand, the black one being connected with the mechanism of the gauge. When the system is first filled to the required height, the spring dial of the gauge shows the height in feet of the water in the system. The face of the gauge is then taken off, and the red dial moved to a point directly under the spring dial, and pointing to the same number on the gauge. As the water in the system evaporates by use, the spring dial drops away from the red dial, indicating less water in the system.

By the use of an altitude gauge at the boiler, the necessity of watching the expansion tank to know the amount of water in it, is avoided, as the gauge at the boiler registers the height of water in feet in the system.

APPROXIMATE RADIATING SURFACE TO CUBIC CAPACITIES OF SPACE TO BE HEATED.

One Square Foot of Radiating Surface will Heat.	CUBIC FEET OF AIR.		
	In Dwellings, School-Rooms and Offices.	In Halls, Lofts, Stores and Factories.	In Churches and Large Auditoriums.
With direct hot-water radiating surface.	30 to 50	60 to 80	90 to 150
With indirect hot-water radiation.	15 to 35	20 to 45	60 to 100
With direct hot-water radiating surface.	50 to 80	70 to 100	160 to 250
With indirect hot-water radiation.	40 to 50	55 to 75	100 to 150

Starting a hot water heating plant. The expansion tank should always be placed in position at the same time as the radiators.

After the system is erected and all connections made, each radiator valve should be packed. The air valves should be attached to the radiators, and should be shut off, preparatory to filling the system with water.

When either or both a hot-water thermometer or altitude gauge are to be used they should be attached at this time, provision being made for connecting them when erecting the mains.

Fill the system with water slowly until the heater and mains are full. If any leaks are discov-

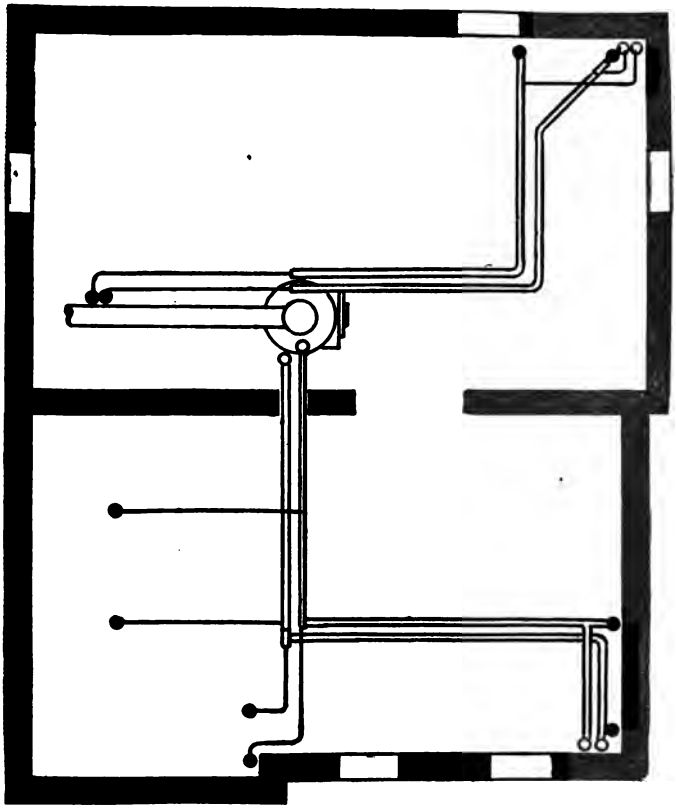


Fig. 76.—Basement.

ered, but not serious, continue to fill the system with water until the water can be drawn freely from the air valves on the first floor radiators.

Open all the radiator valves and start a slow fire, and when the system is tight, raise the tem-

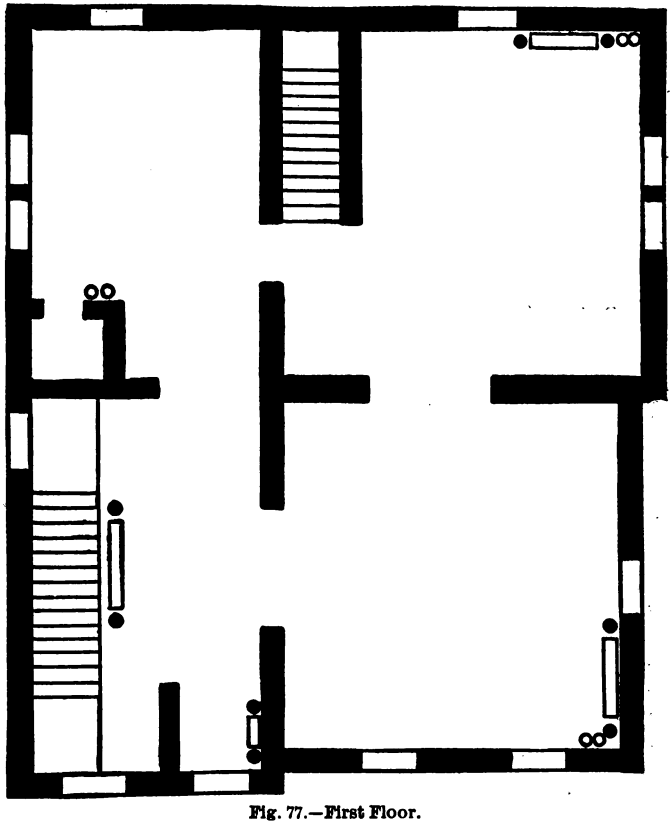


Fig. 77.—First Floor.

perature of the water to the boiling point, or 212 degrees Fahrenheit which should be easily done if all conditions are right.

After a day's test the fire should be let out, and the entire system drained, and all leaks that have

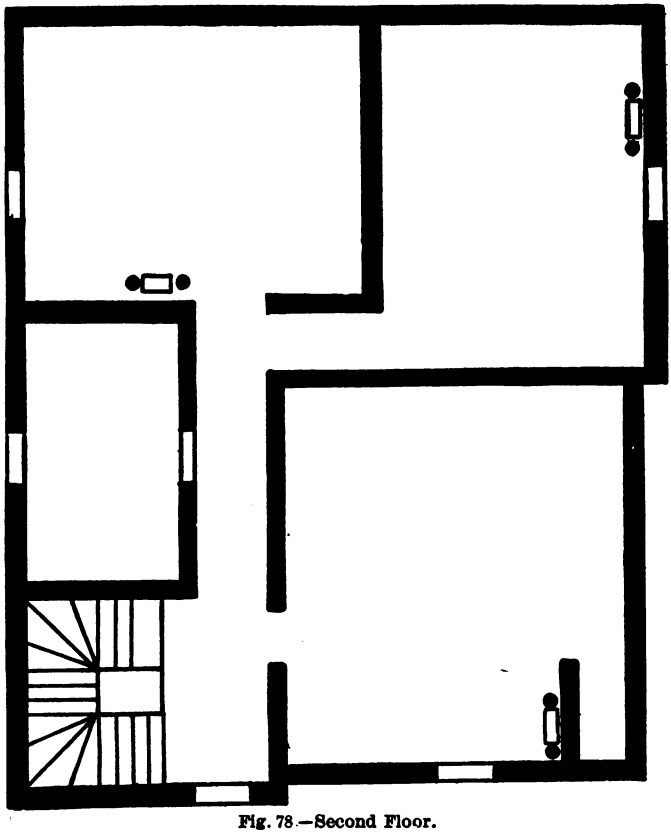


Fig. 78.—Second Floor.

been discovered repaired, when the system should be refilled with fresh water.

Hot water heating plant. The following illus-

trations shown in Figs. 76, 77 and 78 are the plans for a nine room house, heated by a double-main hot water system. The boiler, water, mains, piping to radiators, and the radiators are all plainly shown.

SPECIFICATIONS AND CONTRACT FOR A HCT WATER HEATING PLANT.

We hereby agree to furnish and install in your residence,.....Street, a Hot Water Heating Plant under the conditions, and for the price hereinafter named, and in accordance with the following specifications:

Boiler—To provide and set up in basement one No.....Hot Water Boiler, having a rated capacity of ..... square feet, and furnished with a set of fire and cleaning tools.

Foundation—The owner is to provide a suitable foundation for the boiler of brick or concrete.

Smoke Pipe—The smoke collar of the boiler to be connected to the chimney flue by a .. inch galvanized iron smoke pipe, closely fitted and provided with a choke damper.

Chimney—The owner shall provide a chimney flue of proper size and height to secure sufficient draft.

Fittings—The mains, risers and branches to be of ample area, properly graded. The mains to be

supported in the basement by neat, strong hangers, secured to ceiling joists. All fittings to be of best grade cast iron to be used.

Floor and Ceiling Plates—Where risers and radiator connections pass through floors and ceilings, place bronzed or nickel-plated floor and ceiling plates.

Valves—Each radiator to be furnished with a nickel-plated wood-wheel, quick opening radiator valve.

Union Ells—The return end of each radiator to be provided with a nickel-plated elbow, with union coupling.

Air Vents—Each radiator to be furnished with a nickel-plated air valve, with key or wood-wheel.

Water Supply—The owner is to provide a connection in the water service pipe, near the boiler, for the water supply.

Expansion Tank—Provide and place in proper position a heavy galvanized iron expansion tank, complete with water gauge.

Altitude Gauge—Furnish and attach in proper position on boiler one 5-inch Altitude Gauge with stop cock.

Estimating. Make a careful survey of the location, construction and exposure of the building to be heated, and take accurate measurements of the size of the glass surface and exposed walls of the rooms in which the radiators are to be placed.

Having ascertained the total amount of radiation, select a heater having a rated capacity of 50 per cent in excess of the total radiation, which for the average system will allow for the duty imposed by the mains and provide a margin of 20 per cent.

Make a plan of the basement to scale, locate the heater, and lay out the pipe system, putting down the size of the mains and the branches.

From the plan obtain the number of lineal feet of each size of pipe, including the risers, also the number and size of all fittings.

Allow one air valve for each radiator.

The number and size of the floor and ceiling plates may be counted from the number and size of risers that will pass through the floors and the ceilings.

The length of pipe covering may be obtained from the size and number of lineal feet of pipe in the mains.

Smoke Pipes. Steam boiler smoke pipes range in size from about 8 inches in the smaller sizes to 10 or 12 inches in the larger ones. They are

generally made of galvanized iron. The pipe should be carried to the chimney as directly as possible, avoiding bends, which increase the resistance and diminish the draft. When the draft is known to be good the smoke pipe may purposely be made longer to allow the gases to part with more of their heat before reaching the chimney. Where a smoke pipe passes through a partition it should be protected by a double perforated metal collar at least 6 inches greater in diameter than the pipe.

The top of the smoke pipe should not be placed within 8 inches of exposed beams nor less than 6 inches under beams protected by asbestos or plaster. The connection between the smoke pipes and the chimney frequently becomes loose, allowing cold air to be drawn in, thus diminishing the draft. A collar to make the connection tight should be riveted to the pipe about 5 inches from the end, to prevent its being pushed too far into the flue.

Chimney Flues. Flues, if built of brick, should have walls 8 inches in thickness, unless terra cotta linings are used, when only 4 inches of brick work is required. Except in small houses, where an 8x8 flue may be used, the nominal size of the smoke flue should be at least 8x12, to allow a margin for possible contractions at offsets, or for a thick coating of mortar. A clean out door should be placed at the bottom. A square flue cannot be

reckoned at its full area, as the corners are of little value. An 8x8 flue is practically very little more effective than one of circular form 8 inches in diameter. To avoid down drafts the top of the chimney should be carried above the highest

Dimensions of Chimney Flues for Given Amounts of Direct Radiation

Square Feet of Steam Radiation	Diameter of Round Flue	Square or Rectangular Flue
250	8 inches	8 in. x 8 in.
300	8 inches	8 in. x 8 in.
400	8 inches	8 in. x 8 in.
500	10 inches	8 in. x 12 in.
600	10 inches	8 in. x 12 in.
700	10 inches	8 in. x 12 in.
800	12 inches	12 in. x 12 in.
900	12 inches	12 in. x 12 in.
1000	12 inches	12 in. x 12 in.
1200	12 inches	12 in. x 12 in.
1400	14 inches	12 in. x 16 in.
1600	14 inches	12 in. x 16 in.
1800	14 inches	12 in. x 16 in.
2000	14 inches	12 in. x 16 in.
2200	16 inches	16 in. x 16 in.
3000	16 inches	16 in. x 16 in.
3500	18 inches	16 in. x 20 in.
5000	18 inches	16 in. x 20 in.

point of the roof, unless provided with a suitable top or hood.

Fuel Combustion. Combustion is one form of chemical action, accompanied by the generation of heat. When such action takes place slowly the heat produced is almost imperceptible, but when it takes place rapidly, as in the burning of wood,

coal, etc., the heat becomes intense. In the burning of ordinary fuel, the carbon and hydrogen of the coal combine with the oxygen of the air and produce combustion, without which no material results may be obtained from the fuel.

Combustion depends upon the presence of oxygen, without which it cannot take place.

Combustion is estimated by the number of pounds of fuel consumed per hour by one square foot of grate surface.

One square foot of grate will consume about 5 pounds of hard coal per hour, or about 10 pounds of soft coal, under a natural draft.

For 7½ to 10 pounds of coal consumed, one cubic foot of water will be evaporated.

A fire of a depth of 12 inches will do more efficient work than one of less depth.

The use of too large coal is attended with large air spaces between the pieces, and this large amount of air is too great for the gases escaping from the combustion of the coal, allowing the gases to escape into the chimney flue unburned.

The use of too small coal is not advisable, as it packs down so compactly as to prevent the admission of the proper amount of air through the grate to produce good combustion.

FURNACE HEATING.

Furnace Heating. Since 1 square foot of glass will transmit about 85 heat units per hour when the difference between the inside and outside temperature is 70 degrees, to ascertain the total loss of heat by transmission multiply the exposed glass surface by 85.

If the air enters through the register at 140 degrees, under zero conditions, it is plain that one-half the heat supplied is carried away by the air escaping at 70 degrees the other half being lost through the walls and windows. Therefore, twice the amount of heat lost by transmission must be supplied by the furnace.

As 8000 heat units are utilized per pound of coal burned in a well proportioned house heating furnace, with a maximum coal consumption of 5 pounds per square foot of grate surface per hour there are consequently $8000 \times 5 = 40{,}000$ heat units per hour per square foot of grate surface transmitted to the air passing through the furnace. Dividing the total loss of heat per hour (that is the total exposure in terms of the exposed glass surface) by 40,000 will give the required grate surface in square feet, from which the diameter of the fire pot in inches may be readily determined.

That is: $$\frac{\text{Total Exposure} \times 170}{40{,}000}$$

$$= \frac{\text{Total Exposure}}{235} = \text{required grate surface.}$$

Furnaces. In the furnace shown in the illustration at Fig. 79 the combustion drum from top to bottom consists of one sheet of steel, its seams being riveted until gas-tight so that where the sheet is lapped it is practically welded. The same gas-tight workmanship is maintained in the extra radiating drum and in the furnace throughout. Gas cannot get through the heating surface at any point. The material used is of the best quality low-carbon, steel plate, a metal that is uniform in texture and composition, and anti-corrosive, ductile, and possessed of a tensile strength of 60,000 pounds to the square inch. In a cold state it may be worked almost as copper plate may be, it may be flanged, double-seamed, twisted, drawn out, doubled up, and welded and the process may be continually repeated. A piece one-fourth of an inch thick may be drawn as thin as a piece of writing paper without cracking or checking. Containing less than one-fourth of one per cent. of carbon, mild in quality and homogenous in structure, it is absolutely impermeable to gases, and having a uniform expansive quality throughout its entire mass, it has neither fibre to tear nor sand to drop, as is the case in cast metals.

It may be said of the ordinary furnace that fuel

is put in at the door and heat let out at the smoke hole—let out either as soot and gases that have not

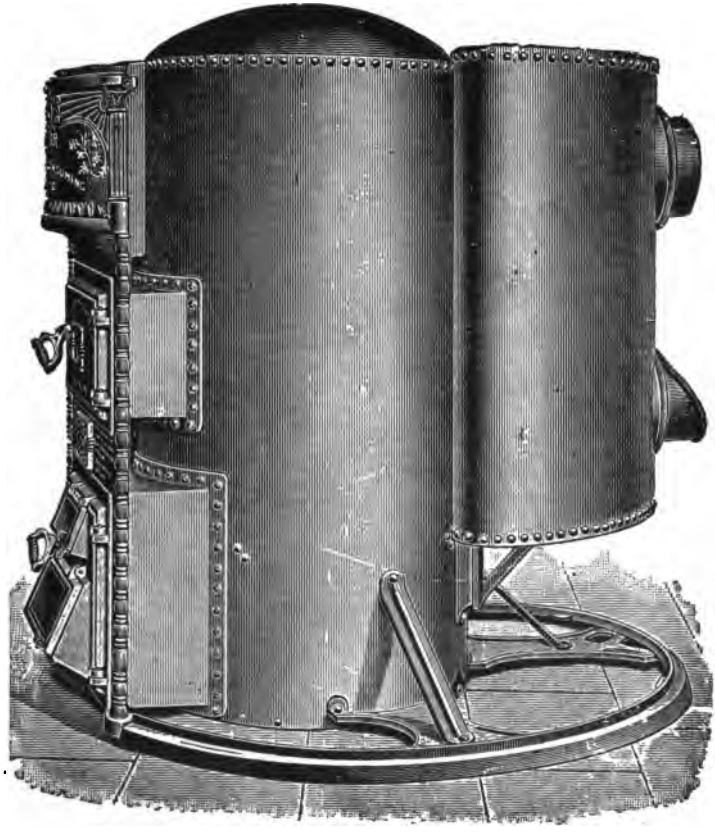


Fig. 79.

been ignited, or as heat that must be wasted through the flue, because efforts to retain it would

cause a choking of the smoke-passage. In other words, it has a practically direct draft because of its imperfect system of fuel combustion.

This is really a double furnace. Combustion takes place in the first, or fire drum, which in itself possesses a very great radiating surface. From this, before reaching the smoke outlet, the products of combustion have to enter and travel a long distance through the second drum. This drum, by actual measurement, contains more heating surface than some of the heaters upon the market contain altogether. This supplementary drum is made in two forms—crescent shape and round, the latter with an open center. The course of the products of combustion being such that heat is brought directly against every part of the inside of the surface, while the air passes against every part of the outside, so that there is not only long retention of the heat inside, but an effective use of it by contact with the air from the outside. A question always arising in the mind that whether or not, with such a long and indirect passage way, there will not be choking or clogging. There will not be. Herein is where the effective combustion is demonstrated. With a good smoke flue and with ordinary good care, this drum will not require cleaning oftener than once a year. More than this, the heating surface will remain practically free from soot-coating, so that it is always effective for service.

Fig. 80 is a partial sectional elevation of the furnace previously described, while Fig 81 shows

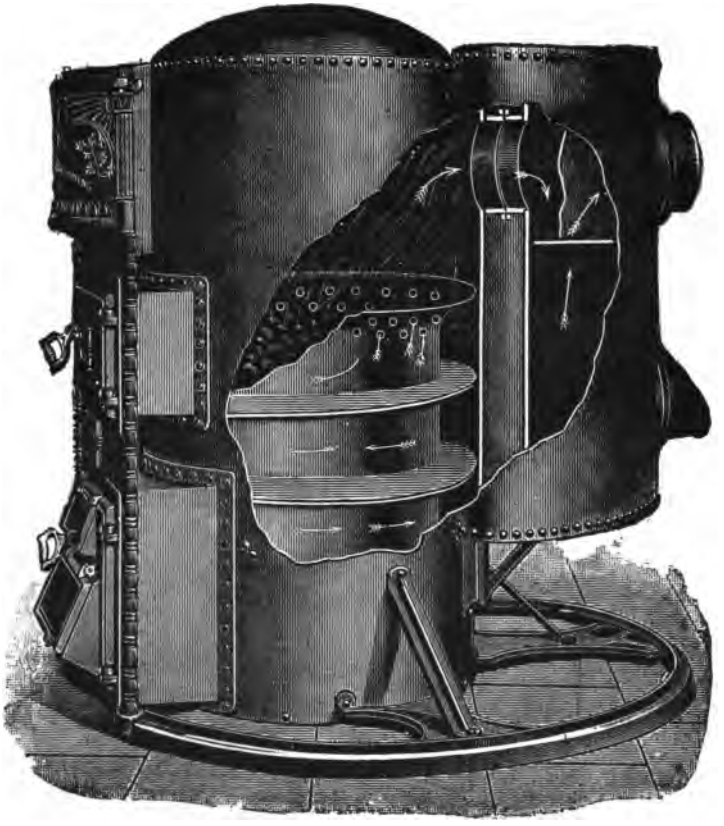


Fig. 80.

the same furnace with a water heating device which forms a portion of the fire pot as shown.

The water-back itself is shown in Fig. 82. An encased type of furnace with additional drum also

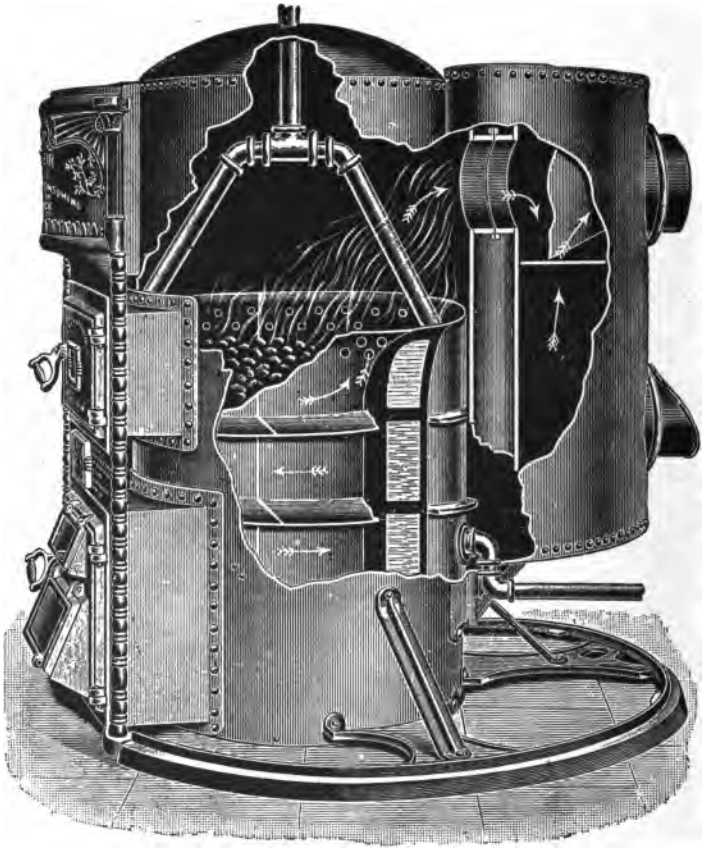


Fig. 81.

built in with the furnace proper is shown in Fig. 83. A water tank for furnishing hot water is also

provided as shown in the illustration. Check draft dampers for controlling the temperature of the furnace are shown in Fig. 84.

General instructions. To obtain proper results and to convey all the warm air that a furnace may produce, to the rooms to be heated, the following rules should be observed:

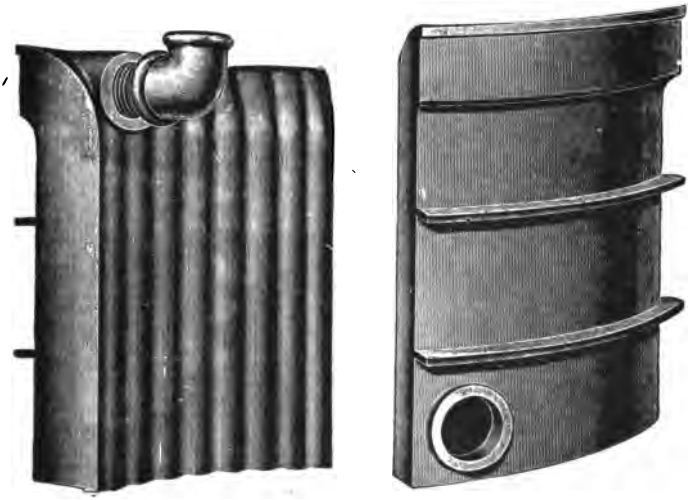


Fig. 82.

Put in a furnace of sufficient capacity.

See that the chimney is of proper size and has good draught.

If possible set the furnace under the center of the house, so as to equalize the length of the hot air pipes.

Hot air pipes should be of the proper size, with a good elevation from the furnace to the register, avoiding long runs and abrupt turns.

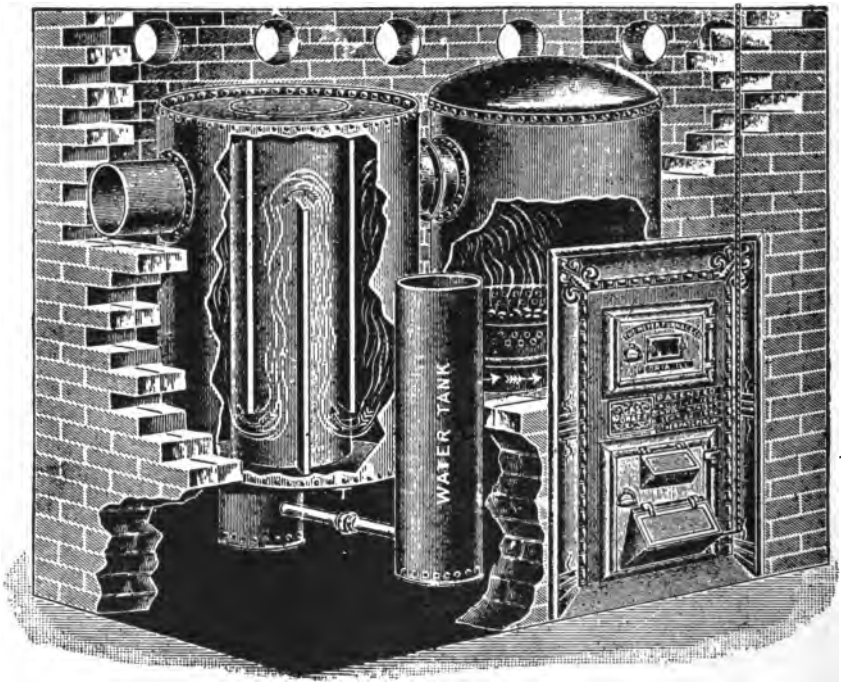


Fig. 88.

The cold air pipe, if taken from the living room, should be at least 85 per cent of the combined area of all the hot air pipes.

All holes or openings in the foundation must be closed to prevent the hot air from being chilled.

Good workmanship and practical application of the same always insures good results.

Proper Size of the Furnace. Some furnaces are

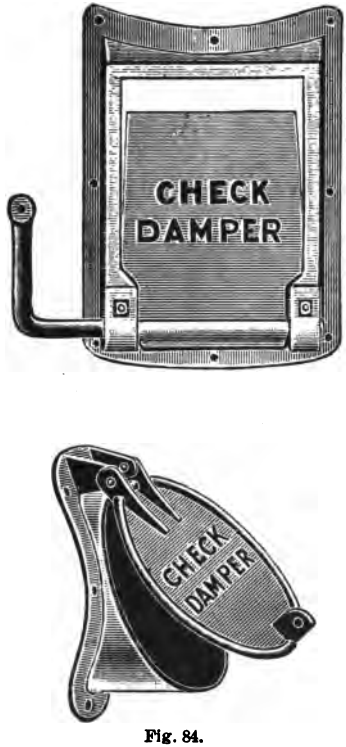


Fig. 84.

rated far above the amount of their actual heating capacities. Combining this with the fact that some dealers expect to sell a consumer only one furnace,

and therefore consider only the first profit and pay little attention to results, has led to the general demand of the prospective buyer to ask for a furnace of one or two sizes larger than the one figured on.

The table of capacities of furnaces are based on scientific figures and years of actual test and experience. Under reasonable conditions a furnace selected according to this rating will heat the building to the proper temperature.

Proper Size of the Chimney. The chimney should start from the floor of the cellar so as to allow for a clean out underneath the smoke pipe. It should continue in a straight line to at least 2 feet above the highest point of the roof, if necessary to offset, care should be taken not to contract the size, a 10 inch round or an 8 by 12 inch square is a good flue for almost any size of furnace. For a small furnace a straight chimney, with an 8 by 8 inch flue will answer the purpose.

A chimney 4 inches wide will seldom give satisfaction. As a great deal depends on a good chimney, this very important feature should never be overlooked.

Location of the Furnace. There may be conditions that make it impractical to set the furnace under the center of the house, but the best results are always obtained when it is possible to do so. If it be necessary to set the furnace toward one end of building, it is best to favor the north

and west. Drainage conditions often govern the depth of cellar. If possible it should be at least 7 feet under the joists.

Hot Air Pipes. There is no rule that would apply to the size of the pipe for certain rooms. The location of the furnace, the length of the pipes and the exposure of the rooms, also their use must be taken into consideration. Ordinarily 8 and 9 inch pipes are large enough for all second and third floor rooms. For first floor rooms, a reception hall with open stairway to second floor, a 12 inch pipe is the best adapted, but 10 inch may answer the purpose in most cases. For parlor, dining and sitting rooms of about 12 by 16 feet or 14 by 15 feet a 10 inch pipe will give good results, 8 and 9 inch should be used for bed rooms. If possible, avoid any bends or turns except an elbow at the furnace and another where it enters the register box or boot. A damper should be put in every hot air pipe close to surface.

All hot air pipes in the cellar should be covered with asbestos. This insures better heating, preserves the pipes and makes them absolutely safe.

Partition Pipes. Use of double pipes is advocated as the flow of air through them is better than if single pipes are used. The reason for this is that with the patented double pipes, the inside pipe has a straight, smooth surface, it does not buckle or warp, thereby reducing its size, but always retains an even and unobstructed passage

from the boot at the bottom to the register head or top.

The outside pipe prevents the inner one from becoming chilled, and also prevents any danger of setting fire to the woodwork by becoming overheated.

Cold Air. This is a very important feature, as an insufficient supply of cold air to the furnace means a lack of warm air in the house. There are different opinions as to the proper place to take cold air from, whether from the outside, from the living rooms, or from the cellar. If taken from the outside, the expansion of air is greater than if taken from the house. A smaller pipe can be used, and therefore costs less to install. The outside air being often very cold, it requires heavy firing to heat it to the required temperature. With good firing satisfactory results can be obtained, but with a low fire cold air may be admitted into the house without being properly warmed.

By taking air from the living rooms, the house can be heated at a minimum cost of fuel, the expense of installation is slightly higher, as it requires a larger pipe, also register faces and other fittings to connect the furnace. By using this method, either one or more pipes can be used. The area of this pipe or pipes should never be less than 85 per cent of the combined area of all the hot air pipes.

The best general results are obtained in this

way, for there is always a circulation, the air is taken out of the rooms, passed over the heated surface of the furnace, and warmed to the proper temperature.

There is only one item in favor of using cellar air, this is the expense of installation, as it costs very little to make the connection—in all other respects it is not advisable to use it.

Openings in Foundation. Great care should be exercised to see that all openings in the basement or foundation walls are properly closed during the cold season, as a current of cold air against any hot air pipes, acts as a damper to the proper flow of air through them.

Good Workmanship. Much depends upon a furnace being properly installed; it is often said that a poor furnace properly installed will give better satisfaction than a good furnace poorly put in.

DIMENSIONS AND HEATING CAPACITIES OF FURNACES.

No.	Height.	Diam.	Height of Radiator.	Height of Casting.	Diam. of Casting.	Weight	Heating Capacity.
	Ft, In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.		Cubic Feet.
24	4—6	2—0	2—0	4—11	4—2	1200	9000 to 80000
28	4—10	2—4	2—4	5—2	4—4	1250	12000 to 25000
30	5—0	2—6	2—6	5—7	4—8	1450	20000 to 35000
33	5—0	2—9	2—9	5—7	5—0	1750	30000 to 50000
36	5—2	3—0	3—0	5—8	5—8	1950	60000 to 80000

THE LOSS OF HEAT BY TRANSMISSION WITH A DIFFERENCE OF 70 DEGREES FAHRENHEIT BETWEEN THE INDOOR AND THE OUTSIDE TEMPERATURE.

The loss in heat units per square foot per hour by transmission for:

8-inch brick wall.	32
12-inch brick wall.	22
16-inch brick wall.	18
20-inch brick wall.	16
24-inch brick wall.	14
Single window.	85
Ceiling (unheated attic).	5
Floor (unheated basement).	4

WIND VELOCITY.

Wind.	Feet per Minute.	Miles per Hour.
Scarcely appreciable	90	1.02
Very feeble	180	2.04
Feeble	360	4.1
Brisk	1080	12.3
Very brisk	1800	20.4
High	2700	30.7
Very high	3600	40.1
Violent	4200 to 5400	47.8 to 61.4
Hurricane	6000	68.1

The United States Weather Bureau defines a gale as a wind blowing 40 miles per hour.

TABLE SHOWING THE PROPER SIZE OF FURNACE PIPES TO HEAT ROOMS OF VARIOUS DIMENSIONS WHEN TWO SIDES ARE EXPOSED.

Temperature at Register 140 degrees, Room 70 degrees, Outside 0 degrees. Rooms 8 to 17 Feet in Width Assumed to be 9 Feet High. Rooms 18 to 20 Feet in Width Assumed to be 10 Feet High. For Other Heights, Temperatures or Exposures Make a Suitable Allowance. When First-Floor Pipes are longer than 15 feet use one size larger than that stated.

Width of Room.	Length of Room.								
	8	9	10	11	12	13	14	15	16
8	7 8	7 8	7 8	7 8	7 8	7 8	8 9	8 9	8 9
9		7 8	7 8	7 8	7 8	8 9	8 9	8 9	8 9
10			7 8	7 8	8 9	8 9	8 9	8 9	8 10
11				8 9	8 9	8 9	8 9	8 10	8 10
12					8 9	8 9	8 10	8 10	8 10
13						8 10	8 10	8 10	9 19
14							8 10	9 10	9 10
15								9 19	9 11
16									9 11

One 12-inch pipe = two 9-inch pipes.
One 13-inch pipe = two 10-inch pipes.
One 14-inch pipe = two 11-inch pipes.
One 15-inch pipe = two 12-inch pipes.
One 16-inch pipe = two 12-inch pipes.
One 17-inch pipe = two 13-inch pipes.

In the space opposite the numbers indicating the length and width of room, the lower number shows the size pipe for the first floor, the upper number the size pipe for second floor.

For third floor use one size smaller than for second floor.

For rooms with three exposures increase pipe given in table in proportion to exposure.

For halls use pipe of ample size to allow for loss of heat to second floor.

THE APPROXIMATE VELOCITY OF AIR IN FLUES OF VARIOUS HEIGHTS.

Outside temperature 32 degrees Fahrenheit. Allowance for friction 50 per cent. in flue one square foot in area.

Height of flue in Feet.	Excess of temperature of air in the flue over that out doors											
	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	120°	140°
	Velocity of air in feet per minute.											
5	77	111	136	159	179	199	216	234	250	266	296	325
10	109	156	192	226	254	281	306	330	354	376	418	460
15	133	192	236	275	312	344	376	405	432	461	513	565
20	154	221	273	319	359	398	434	467	500	532	592	650
25	173	248	305	357	402	445	485	522	560	595	660	728
30	189	271	334	390	440	487	530	572	612	652	725	798
35	204	293	360	423	475	527	574	620	662	705	783	862
40	218	311	386	452	508	562	612	662	707	753	836	920
45	231	332	408	478	538	597	650	700	750	800	887	977
50	244	350	432	503	568	630	685	740	790	843	935	1030
60	267	383	473	552	622	690	750	810	865	923	1023	1125
70	289	413	510	596	671	746	810	875	935	995	1105	1215
80	308	443	545	638	717	795	867	935	1000	1065	1182	1300
90	327	470	578	678	762	845	920	990	1060	1130	1252	1330
100	345	495	610	713	802	890	970	1045	1118	1190	1323	1455

The volume of air in cubic feet per minute discharged by a flue equals the velocity in feet per minute multiplied by the area in square feet.

Knowing any two of these terms, the third may be readily found.

$$\text{Velocity} = \frac{\text{volume}}{\text{area.}} \qquad \text{Area} = \frac{\text{volume}}{\text{velocity.}}$$

Example.—Find the area of a flue 20 feet high that will discharge 3,000 cubic feet per minute, when the excess of temperature in the flue over that out doors is 40 degrees.

Opposite 20 in left hand column and under 40 on upper line is the number 319, representing the velocity in feet per minute. The volume 3,000 ÷ 319 = 9.4 square feet, the required area. In estimating the effective height of a warm air flue from a furnace, consider the flue to begin 2 feet above the grate.

THE CAPACITY OF FURNACES TO MAINTAIN AN INSIDE TEMPERATURE OF 70 DEGREES WITH AN OUTSIDE TEMPERATURE OF 0 DEGREES.

Temperature of entering air, 140 degrees. Rate of combustion, 5 pounds coal per square foot of grate surface per hour.

Average diameter of fire pot in inches	Corresponding area in square feet	Total exposure in square feet to which furnace is adapted.
18	1.77	1,110
20	2.18	1,370
22	2.64	1,655
24	3.14	1,970
26	3.69	2,310
28	4.27	2,680
30	4.91	3,080
32	5.58	3,500

The Expansion of Wrought-Iron Steam and Water Pipes. To calculate the amount of expansion in the length of pipes, with different temperatures, take a pipe 100 feet long, containing cold water, or without either steam or water, and being at a temperature of about 32 degrees Fahrenheit. After heating the water in the pipe to 215 degrees, or 1 pound pressure of steam, the pipe will be found to be 100 feet 1½ inches in length, with a rise in temperature from 32 degrees to 265 degrees, or 25 pounds pressure of steam, there will be an increase in length of 1 8/10 inches. From 32 degrees to 297 degrees, or 50 pounds steam pressure, the increase would be 2 1/10 inches. And again, a rise in temperature from 32 degrees to 338 degrees, or 100 pounds pressure of steam, will give an increase in length of 2½ inches.

Wrought Iron Pipe. Wrought iron pipe is now almost exclusively used in heating plants. It is made at a number of factories, and being of standard sizes, pipe bought from different factories will be found to fit the same size of fittings.

It is manufactured from wrought iron of the proper gauge, which is rolled into the shape of the pipe and raised to a welding heat, after which the

edges are welded by being drawn through a die. The small sizes of pipe up to 1¼ inches are butt welded and 1½ inches and larger sizes are lap welded.

Fig. 85.

Fittings. Pipe fittings can be bought from the regular supply houses.

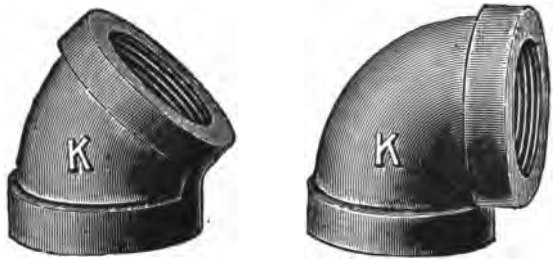


Fig. 86.

Fittings are mostly of cast and malleable iron, except straight couplings, which are usually of wrought iron. Elbows, tees and other fittings,

which can be procured of cast iron, are the best to use, owing to the fact that being of a harder metal than the pipe, and less elastic, they will not yield

Fig. 87.

sufficiently to cause leakage when connections are made. All fittings should be closely examined for flaws before screwing on to the pipe.

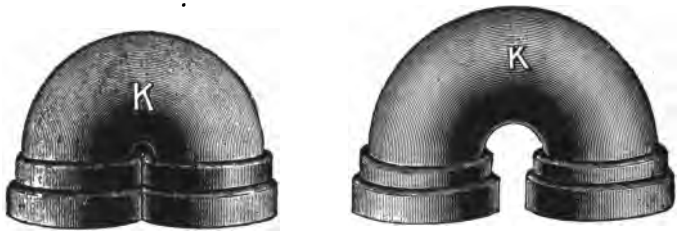
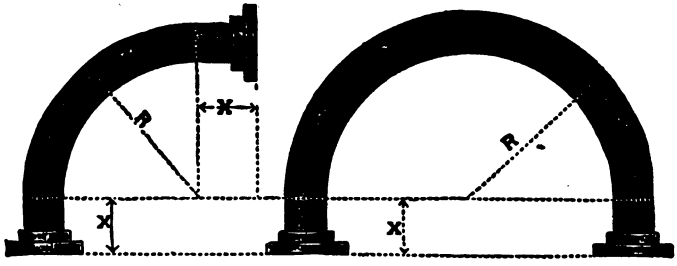


Fig. 88.

Standard cast iron fittings for use in installing steam and hot water heating plants are shown in Figs. 85, 86, 87 and 88.

Pipe Bends. The radius of any bend should not

be less than 5 diameters of the pipe and a larger radius is much preferable. The length X of



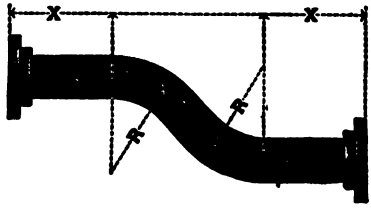


Fig. 89.

straight pipe shown in Fig. 89 at each end of bend should be not less than as follows:

2½-inch Pipe X=4 inches,
3 -inch Pipe X=4 inches,
3½-inch Pipe X=5 inches,
4 -inch Pipe X=5 inches,
4½-inch Pipe X=6 inches,
5 -inch Pipe X=6 inches,

6-inch Pipe X=7 inches,
7-inch Pipe X=8 inches,
8-inch Pipe X=9 inches,
10-inch Pipe X=12 inches,
12-inch Pipe X=14 inches,
14-inch Pipe X=16 inches,
15-inch Pipe X=16 inches,
16-inch Pipe X=20 inches,
18-inch Pipe X=22 inches.

Pipe Machines. The illustrations in Fig. 90 show two portable pipe-threading machines which are compact, moderate in cost, and efficient. For

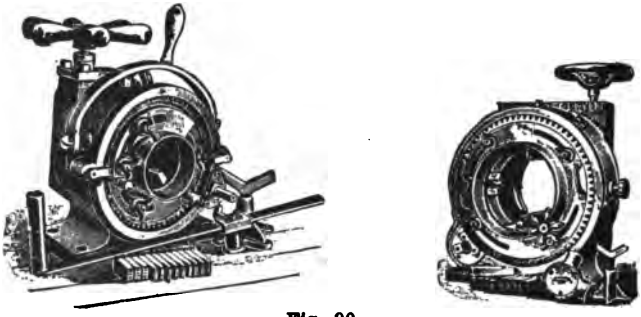


Fig. 90.

the larger sizes of pipe, covering a range of from 2½ to 4 inches they will be found time-saving and convenient devices.

Tools. The tools shown in Figs. 91 and 92 will be found sufficient to meet the ordinary requirements for installing a steam or hot-water heating

Fig. 91.

is fitted for the use of gas, and the field of discovery in the use of gas for domestic purposes appears to be as great as that of electricity.

Gas Supply Pipe. The gas supply pipe should be connected to the main in the best possible manner. The pipe should be wrought iron, with fittings, if any, of malleable or wrought iron. Cast-iron fittings should not be used as they crack easily. The service pipe should be laid with an incline to the main in the street, as the earth which surrounds the pipe being cold causes some of the gas to condense and become liquid. With a fall in the supply pipe to the street the condensation can therefore flow back into the main pipe.

With the supply pipe laid in this way there will be no flickering of the gas or any unsteady pressure.

The gas supply pipe from the street main should never be less than one-inch pipe. The meter connection pipes should always be of one size larger than the meter couplings. All drops should be not less than $\frac{3}{8}$-inch pipe.

Street Supply Pipe. It is necessary to have the house supply pipe rest on a solid foundation. It often happens that in excavating the trench for the supply pipe it is dug too deep, or it may be dug level, and as the pipe must be pitched back to the main, it will have to be blocked up. Do not block up a supply pipe on filled-in earth. Start the blocking from the bottom of the trench or from

the lowest excavated part. There is no special amount of pitch required for such pipes as the more pitch they have the less liability they will have to form a water trap. After the pipe is all laid, properly graded and blocked, test the pipe, for the purpose of ascertaining if there are any leaks, before the pipe is covered up. The pipe being found perfectly gas tight, the trench can now be filled up. It is a good plan to remain on the ground and superintend the work of properly filling the ditch as the average laborer who is engaged to do the filling of such ditches has not sufficient knowledge of the work to handle the pipe with the necessary care. It is not an unusual thing to find the gas supply pipe leaking badly, after being covered over, by allowing heavy stones to fall into the ditch by carelessness on the part of the laborers.

Frost in Pipes. The flow of gas is retarded by frost even where the supply pipe has sufficient pitch, if it be in too cold a place and not properly protected from the cold. This occurs generally in the main supply pipe where it passes under the sidewalk, and as a large amount of gas passes through the supply pipe, a large amount of moisture comes with the gas. It is this moisture which freezes to the sides of the pipe, like heavy frost on a window, but much coarser, and looks very much like coarse salt. It will keep on accumulating, gradually filling up the pipe toward the center

from all sides, until the pipe is entirely filled and the flow of gas arrested.

To remedy this difficulty the pipe should be covered with some felt or other material, dry sawdust may be also used and placed in a box around the pipe. By striking the pipe a sharp blow with a hammer the frost will fall from the sides of the pipe and lie at the bottom of the pipe. This does not clear the pipe entirely, but will allow the gas to flow through the upper part of the pipe. This frost cannot be blown back into the main and to clear the frost out entirely alcohol must be poured into the pipe at the meter connection, a half pint or more, which will melt the frost and carry the water which is formed into the main.

Fittings. Gas fittings should be of malleable iron in preference to cast iron as they are lighter and neater in appearance, besides being much stronger. Standard fittings for use in gas lighting work are shown in Figs. 94, 95 and 96. Union elbows and tees are shown in Fig. 97 and gas service cocks in Fig. 98.

Connecting a Meter. The gas pipes in the building, as well as the supply pipe from the street, should be tested before the meter is connected, to avoid the possibility of damaging the meter by any sudden pressure. The supply pipes should also be blown out so that the liability of dirt being carried into the meter by the gas will be obviated.

After connecting the meter care should be taken

to turn on the gas slowly until the pressure has had a chance to equalize on the distributing side. This prevents a sudden strain on the meter. A meter should not be set in a place warmer than 100 or colder than 40 degrees Fahrenheit, as the oil in

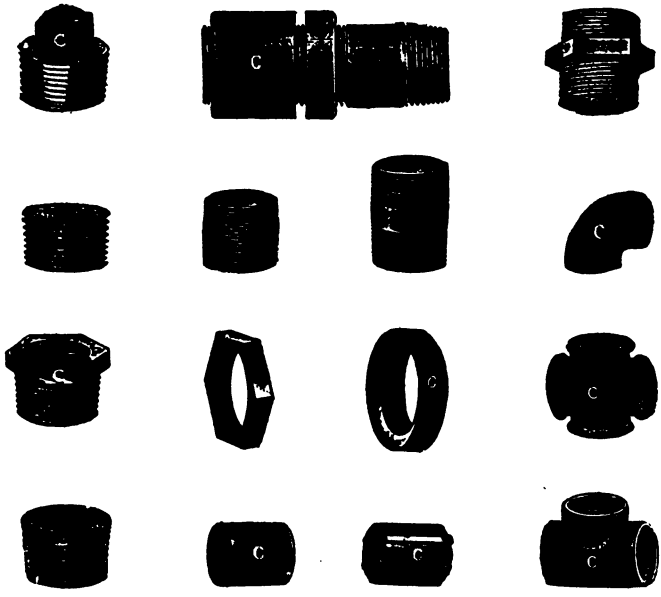


Fig. 94.

the meter diaphragms is very susceptible to heat or cold.

Reading a Meter. One complete revolution of a hand registers the number of cubic feet marked above the dial.

STREET ELBOWS

ELBOWS

DROP ELBOWS

DROP TEES

WALL PLATES

CHANDELIER HOOKS

FOUR-WAY TEES

CROSS OVERS

REDUCING COUPLINGS

EXTENSION PIECES

Fig. 95.

STEAM AND GAS FITTINGS

ELBOWS

CAST IRON

STRAIGHT

REDUCING ELBOWS

CAST IRON

45° ELBOWS

CAST IRON

ECCENTRIC TEES

CAST IRON

REDUCING TEES

CAST IRON

Fig. 96.

WITH FEMALE UNION

WITH MALE UNION

WITH FEMALE UNION

WITH MALE UNION

Fig. 97.

Put down the figures on each dial, that the hand has just passed, and add two ciphers. The num-

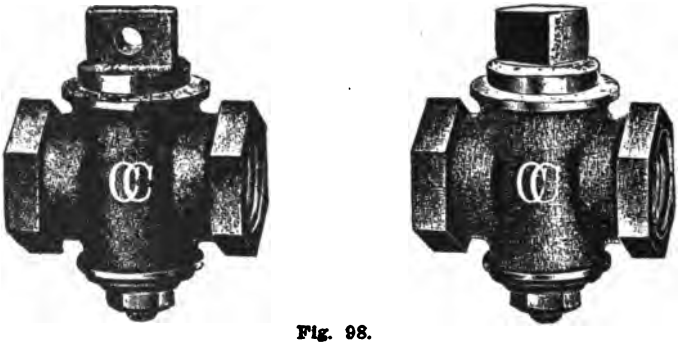


Fig. 98.

ber obtained will be the amount of gas in cubic feet that the meter has measure. From this amount

subtract the last reading of the meter and the result is the amount of gas consumed in the intervening period.

A type of meter and one of the most used is shown in Fig. 99, and the dial plate of a gas meter in Fig. 100.

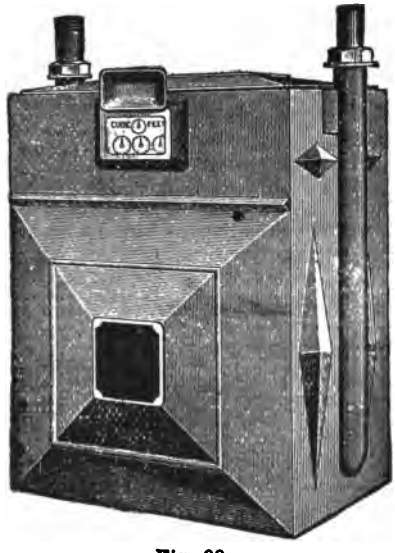


Fig. 99.

Blow-torch. In working around gas fixtures that are in place, the gas fitter should be very careful about the walls and ceilings and not blacken them with the blow-torch in case he has to heat a joint for the purpose of connecting. Proper tools should be at hand to do this work with, and in

place of using gasoline or some other kind of oil in the torch, the best kind of alcohol should be

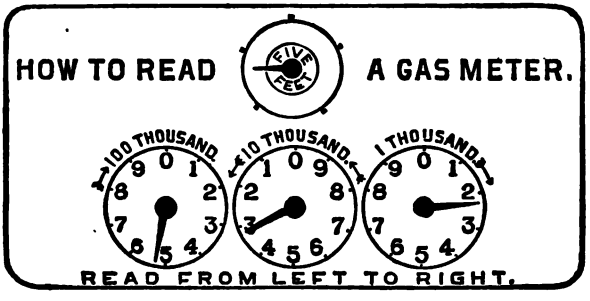


Fig. 100.

used, so that there will be no smoke from it to dirty the walls or ceiling. Fig. 101 shows a gas

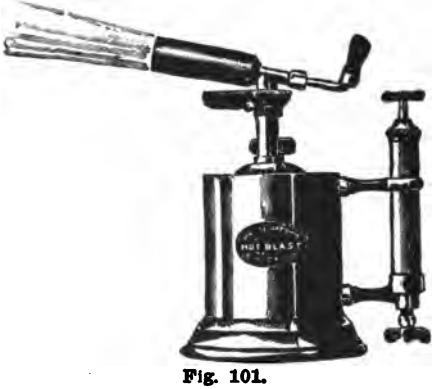


Fig. 101.

fitter's blow-torch, made in the best possible manner and adapted for many purposes.

Mantle Lamp. The mantle lamps of which there are a great many different varieties, resem-

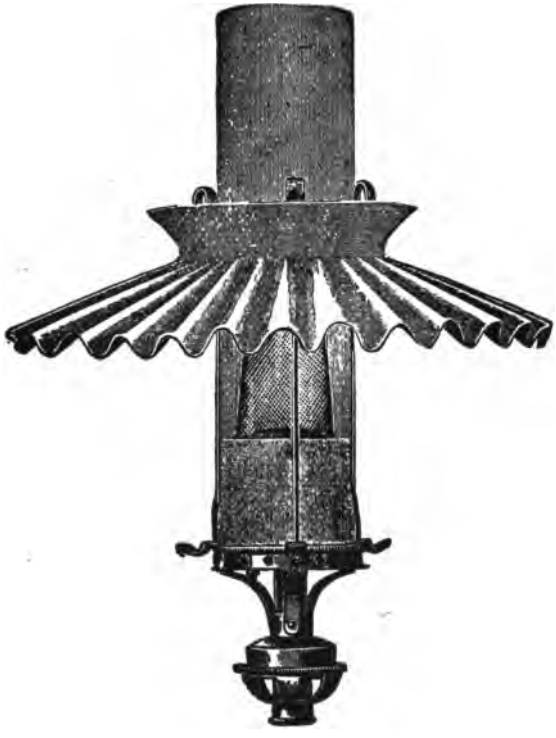


Fig. 102.

ble somewhat the old-fashioned round or Argand type of burner, but the manner in which the light is produced is entirely different in the mantle

lamp. The light produced by this lamp does not come from the flame itself, as in the case of an ordinary gas burner, but from the mantle, and is due to the intense heat to which it is subject by the action of the Bunsen flame within the lower end of the mantle. Fig. 102 shows one form of a mantle lamp.

In transferring a mantle from its box to the burner, take the two ends of the string in one hand and lift the mantle out of the paper tube. By holding the top part of the burner in the other hand and below the mantle, the latter can safely be lowered into position. Before fixing the chimney examine the mantle, as a faulty one will be exchanged by the dealer if returned before being lit. A mantle is made up of a regular series of loops, each row connected to the one above, and if at any point a loop does not join the row above, the mantle should be returned as faulty, as it is almost certain to develop a break as soon as used. Other faults, such as broken collars, broken suspending loops, fractured sides, and torn bottoms, are noticeable at a glance.

When lighting incandescent burners, the light should be applied from underneath the chimney, but above the screen which prevents lighting back. Some prefer to light from the top of the chimney, in which case the gas should be turned on sufficient time before the light is applied to allow the gas to expel all the air in the chimney,

so that little or no explosion shall take place, and the mantle may be free from consequent damage.

The breakage of mantles when in position may be avoided by attention to a few rules. Fix incandescent burners only on good sound and clear gas fittings. Where there is much vibration, use one of the anti-vibration frames now on the market, these frames are specially suitable for hanging lights, such as the arc lamps, etc. All pendants for the incandescent light should be supplied with loose joints, and they should never be screwed stiff, or the mantle will break if it gets the slightest knock. In draughty places, such as lobbies, passages, and corridors, a mica chimney is desirable, so as to avoid breakage of the chimney, and to preserve the mantle.

If a newly fixed burner gives an unsatisfactory light, either there may be an insufficient gas supply, or the mantle may be much too wide, perhaps both conditions exist. In the first case the mantle will be well lit all round the bottom with the light getting worse towards the top. If two of the four air-holes in the Bunsen tube are covered by the fingers, the light will at once improve. Therefore, either reduce the amount of air admitted, or increase the quantity of gas supplied. To reduce the amount of air, unscrew the Bunsen tube and fix inside it a piece of card or tin to cover two opposite holes. To increase the gas supply, remove the burner from the fittings, and unscrew

the Bunsen tube, when the gas regulator nipple will be seen to consist of a brass tube having a metal top with small holes, which should be very slightly enlarged. Very handy for this purpose is a hat-pin, ground to a long taper and passed up from the under side. When a mantle is too wide, one side only is incandescent, the other side hanging away from the gas ring. This fault is, of course, easily seen before the burner is used, if, however, the mantle has been lit, the light can be improved by slightly lowering the mantle and, as this is tapered, presenting a smaller surface to the flame. Take off the mantle, lifting it by a wire under the suspending loop. Then place the wire across a glass tumbler with the mantle suspended inside. Take out the support, nick it with a file about ½ inch from the plain end, and break it off, then replace the mantle.

It is noticed that the brilliant light given by a new burner does not last, the light after a fortnight probably commencing to decrease. If kept in use, the mantle top becomes coated with soot and a smoky flame issues. The burners go wrong in a much shorter time if used in a room in which a fire is constantly burning. The cause of this is simply dust, which is drawn in at the air-holes and carried up the Bunsen tube. It cannot pass away owing to the screen, to which it adheres, thus preventing the gas getting away quickly enough to draw in the proper amount of air. To

remedy this, take off the mantle and, with a small brush (an old nail- or tooth-brush), remove the dirt, blowing through the screen afterwards. Then replace the mantle, clean and replace the chimney, unscrew the Bunsen tube, and brush the nipple clean. Blow the dust from the tube and then refix the top. If the mantle is covered with soot, leave the gas half on until the soot is removed. To keep the burners at their best, this process should be done at least monthly. If the burners are in a dusty place they will require more frequent cleaning.

Failure of the bye-pass in arc lamps is a common fault, even in new burners. The bye-pass light may go out after the gas is turned on. In a new burner this is often caused by one of the two set-screws on the side of the burner being inserted too far; in this case, after unscrewing a complete turn, the burner will most likely work. It is sometimes necessary to take out both screws and to remove the grease adhering inside the end of the hole.

Gas Proving Pump. Considerable time will be saved by having a good force pump with which the supply pipe in the street and the house pipes may be tested. A gas proving pump is shown in Fig. 103.

Cleaning Gas Fixtures. If the gas fixtures cannot be kept covered in summer time, they can be kept clean by going over them every two or three

days with a soft, damp cloth, which must not be pressed hard against the fixture, as there will be danger of rubbing off the thin coat of lacquer. All that is to be taken off is the fly-specks, for if they are allowed to remain for more than two or three

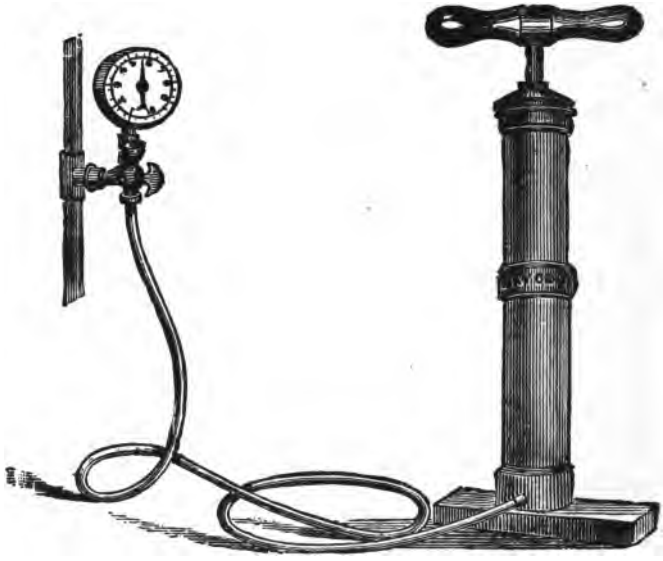


Fig. 108.

days they will eat in through the lacquer and also through the plating and then the more the fixtures are cleaned the worse they will look. No powder or polish of any kind should be used for the purpose of cleaning gas fixtures, as it will at once destroy the only protection a gas fixture has, that is

the coat of lacquer. After using a damp cloth to clean the fixture, dry each part at once with a soft, dry cloth, as it will injure the coat of lacquer to allow water to dry on the fixture. Even the moisture from the hand will sometimes leave a stain that can never be cleaned off.

FLOW OF NATURAL GAS THROUGH A ONE-INCH CIRCULAR OPENING.

Pressure, Inches Water.	Cubic Feet per Hour.	Inches Mercury.	Cubic Feet per Hour.	Pressure, Pounds per Square Inch.	Cubic Feet per Hour.
2	2,041	1	5,168	5	17,186
4	2,897	2	7,632	6	18,989
6	3,542	3	9,305	8	21,778
8	4,116	4	10,552	10	23,388
10	4,563	5	12,019	12	25,479
		6	13,220	15	27,876
		7	14,182	20	33,027
		8	15,316	25	38,002
		9	16,025	30	42,762
		10	16,970	35	48,074
				40	52,761
				50	62,352
				60	71,125

HEIGHT OF COLUMN OF LIQUID TO PRODUCE ONE POUND PRESSURE PER SQUARE INCH AT 62 DEGREES TEMPERATURE.

Water	27.71
Machinery oil	30.80
Mercury	2.04

GAS BURNERS.

While much has been written upon the principle involved in obtaining a light from gas, very little is generally known as to what is required and what is the best means to adopt to secure the greatest amount of light at the least cost, and with the least vitiation of the atmosphere of the room where the light is required. Many and various improvements have been brought forward for the accomplishment of these objects, some require only a very slight alteration to the existing fittings and yet give very excellent results, while others secure a very high illuminating effect and at the same time not only remove the vitiated air which has been used to support the combustion of the flame, but at the same time carry off the air rendered useless for supporting life by the inspiration and absorption of the oxygen.

The principle which is involved in the burning of gas may with advantage be here mentioned. Coal gas contains many very different substances, about one-half of it is hydrogen, one-third marsh gas, and perhaps one-tenth is carbon monoxide.

The three gases mentioned in the statement are of no value as regards the light they will give by

themselves, but they are capable of giving a great heat when ignited, and this heat is utilised for the purpose of rendering white hot the small quantity of hydro-carbons in the gas, and it is this incandescence of the very finely divided carbon particles which makes the flame luminous.

When a gas burner is lighted, the rush of gas from the orifice of the burner causes a current of air to pass upon each side of the flame, and thus supply the oxygen necessary to support combustion, the portion of the flame nearest to the burner is almost non-luminous, and is, in fact, unignited gas enclosed in a thin envelope of bright red flame. That this is really unconsumed gas can be shown by placing the lower end of a glass tube into this portion of the flame and applying a light at the upper end, when the gas issuing from it is seen to burn with an ordinary flame. The reason that this portion of the gas is not luminous is that the quantity of oxygen which is able to get to the flame at this point is only sufficient to cause the outer portion to be in a state of incandescence. That there is solid carbon in the flame may be seen by inserting a piece of cold metal or porcelain in the white portion of the flame, which, by reducing the temperature of the carbon, becomes coated with soot upon the under side. The same effect takes place when the cold air is allowed to blow upon the surface of the flame, the excess of oxygen presented to the flame causing a cooling of

the heating gases and a consequent loss of light, as the particles of carbon are not then sufficiently heated to be made white hot and to give off light, and they then allow the carbon to pass off in the form of soot and to blacken the ceilings and paint of the rooms. This is more likely to occur with high quality gas, which contains more particles of hydro-carbons, and if there be an insufficient supply of oxygen to the flame a larger proportion of soot will be allowed to escape and settle upon the ceilings, etc. Another source of blackening of the ceilings is the nearness of the burners and the absence of a guard over them to deflect and spread the products of combustion over a large space. The real explanation of this effect is that aqueous vapour formed by the burning gas is condensed on the ceiling, and dust particles which are floating in the air are thereby caused to adhere to the ceilings. With high quality gases small burners should be used, so that the gas may be more thoroughly consumed.

It appears that the first burners were simply pieces of pipe with one end stopped up. In the centre of the end was drilled a small hole, and the light given off, principally owing to the shape of the flame, was very small. Then was invented the bat wing burner, which has a slot cut in the dome-shaped top, and this gave a flame somewhat of the shape of a bat's wing, hence the name. Then came the union jet, which is an arrangement very

generally in domestic use at the present day. It consists of a piece of brass tube plugged with a piece of steatite or porcelain with two holes in it drilled at such an angle that the two streams of gas issuing from them meet, and cause the flame of gas to spread and form a flame of horseshoe shape. One of the special points to be noticed in these burners is that the holes in them should be of comparatively large size, and the pressure of the gas when delivered from the burner reduced to the lowest point at which a firm flame can be maintained. This can be done best by means of what is known as a governor, which is in effect a self-acting valve which allows only just so much gas to pass as may be required.

Passing on to the more modern styles of burners, of which there are many patterns, such as the regenerative burners, it is found that all these embody the same principle, which is to use the heat generated by the flame to heat the gas supply and the air supply so that the cooling effect of the air, which causes the blue portion of an ordinary flat flame, is considerably reduced, and the particles of carbon are rendered more rapidly incandescent, and, being heated to a greater temperature, attain greater luminosity and are kept for a longer period at this white heat.

The earliest arrangement of such a burner was invented in 1854, and consisted of an argand burner with two chimneys, one outside of the other,

the air supply to the flame having to pass down between the two glasses, and so to become heated before it was led to the bottom of the burner. This answered very well, but the breakage of the chimney glasses was a considerable expense, and debarred many from adopting the system. This trouble is quite overcome in the modern regenerative burners, as the chimneys are made of metal and the burner is inverted, so that the flame is spread outwards instead of, as in the argand burner, upwards. The regenerative burner gives a light having four times the illuminating power of the flat-flame burner.

With the incandescent burners, quite a modern invention, the principle of admitting air to mix with the gas before lighting is employed as in the Bunsen heating burner, and this, while taking away the luminosity of the flame, causes it to give off a much greater amount of heat, this heat being utilised to render a mantle of rare earths incandescent or white hot. These mantles are made conical in shape, and when made white hot emit a most pleasing white light, which is about five or six times more intense than that given off by the ordinary flat flame burner.

With a properly arranged ventilating regenerative burner, consuming 20 cubic feet of gas per hour, and properly fitted, not only can all its own product of combustion be removed, but also the air vitiated by breathing can be removed at the rate of

more than 5,000 cubic feet per hour from the upper part of the room.

The comparative quantity of air vitiated by different illuminants giving the same amount of light is shown by the following table:—

Gas burnt in union jets.....	1
Lamp burning sperm oil	1.6
Lamp burning kerosene oil.....	2.25
Tallow candles	4.35

From this table it will be seen that kerosene lamps use up more than twice the amount of the oxygen of the air that gas does, while tallow candles use more than four times the amount.

For a light of 32 candle-power, tallow candles would vitiate as much air as would be required by about 36 adult persons, kerosene oil lamps as much as fifteen adults, while gas varied from an amount of air required for nine and a half adults when a batwing burner was used, to eight and a half when an argand burner was used. In these experiments not only was the quantity of oxygen consumed taken into consideration, but carbon dioxide and the water vapour were all taken account of.

Special attention must be directed to the necessity of having burners suitable to the quality of gas which is being used. It may be taken as a fairly general rule that the higher the illuminating power of the gas the smaller the burner should

be. With unsuitable burners, not only blackening of the ceilings, but a far lower state of efficiency as regards the illuminating power of the light obtained from a given quantity of gas will result.

The effect of using bad burners is primarily that the light capable of being developed from the consumption of a definite quantity of gas is not obtained, consequently more gas is burnt than necessity requires, in other words, gas is wasted, and with imperfect combustion, deleterious products are given off, vitiating the atmosphere and endangering health.

That the burners which are most economical in gas consumption are the most expensive at first cost is certainly the case to some extent, but the amount of the saving effected by their use quickly repays the first cost, and thereafter the money saved goes directly into the pocket of the user of the burner. The incandescent burner is the most economical burner that is at present known, and where gas is at a high price it is a very distinct advantage, as the quantity of gas required for a given amount of light is only about one-fifth of that used with the ordinary burner. Then comes the argand burner, which is superior to the union jet or flat-flame burner, but in all these an arrangement known as a governor is generally to be found, by which is regulated the quantity of gas that can find its way to the point of ignition,

and, if only just sufficient is allowed to pass so that none is wasted, gas is economised. These governors are also made for use with the ordinary flat-flame burner.

As has been said, the principal gas burners now in use are the flat-flame, argand, and incandescent. Flat-flame burners embrace the union jet, or fishtail, and the batwing. In the union jet or fishtail the gas issues through two apertures in a steatite plate inserted in the top of a cylindrical brass tube, threaded at its lower end for the purpose of attaching to a gas-fixture. The holes in the steatite tip through which the gas issues are inclined towards each other at an angle, so that the gas issues in two streams which unite into one flat flame at right angles to a plane passing through the two holes. One of the reasons of the adoption of steatite for the tip of the gas burner was the fact that it required a very high heat to harm it. Steatite is a natural stone found in various parts of the world, principally in Germany. Chemically it is a double silicate of magnesium, and a substitute for the natural substance may be obtained by mixing silicate of magnesium and silicate of potash. Natural steatite is of a very fine grain, and softer than ivory, it admits of being worked to a very fine polish, but after it has been burned in a kiln it becomes harder than the hardest steel, and will resist a very high temperature, about 2,000° Fahrenheit. In forming the steatite

into burner tips, the material is finely powdered, moistened with water, and kneaded into a plastic condition, after which it is moulded to the requisite shape and finally burnt to harden it. The diameter of the orifices in the steatite tips, through which the gas issues, differs in size, the aim being in each case to produce a flame of a thickness suited to the quality of the gas the burner is intended to consume.

The batwing burner resembles the fishtail or union in its general features, but differs in the manner in which the gas issues from it. In this form of burner the hollow tip is made dome-shaped and has a narrow slit cut across it and extending some little distance down. The slit varies in width to suit different qualities of gas. The batwing burner requires less pressure than the union jet, with the result that the gas issues with less force, so that the flame produced in burners of this class is not so stiff as that obtained with a union burner. Consequently it is necessary to employ globes with burners of this description in order to protect them from draught, which would cause them to flicker and smoke.

GAS STOVES AND FIRES.

An examination of the principles of gas stoves, and a consideration of the advantages and disadvantages of these heating appliances, may appropriately precede any description of gas stoves themselves. A point often ignored in the heating of rooms is that a room will not feel warm until its walls reach the same temperature as the air which it contains. Until this occurs, the room will feel draughty, owing to the fact that the walls are depriving the air of the heat given out by the stove.

It is necessary to examine the conditions of the room or building to be heated before making any calculation as to the amount of gas required to heat it. Architects calculate the cubical contents of the room, and gauge from this the size and character of the heating appliances required. A better plan is to calculate the area of the wall surface, and, in ordinary dwelling-houses, allow that one-half a heat unit is absorbed by each square foot per hour for each degree Fahrenheit rise after the necessary warming up is complete.

The number of heat units generated per cubic foot of gas of sixteen candle-power, theoretically is 670 to 680, therefore, to raise the temperature

in a room which has been once warmed, it is necessary to allow a consumption of 1 cubic foot for every 1,300 square feet of wall surface. For the preliminary heating, however, considerably more than this is required, and as there should be a change of air in the room about every twenty minutes, practically three-fourths of the heat produced by the stoves passes away by ventilation, and consequently about four times the above-mentioned quantity of heat is required to raise the temperature of a room from the commencement, when it is at about the same temperature as the external air.

It was at one time recommended to fix a row of Bunsen burners in front of or underneath an ordinary coal fire-grate, filled either with black fuel, made of fireclay, or with small coke. It gave a very cheerful appearance, but it was found that the quantity of coke used, together with the consumption of gas, rendered the plan uneconomical. Many persons set a high value upon the cheerful appearance of this arrangement, and are willing to pay for it, and makers have brought forward improvements by which a saving of gas is effected. Still, gas fires in ordinary coal grates can only be recommended in preference to gas stoves when economy is not essential.

Stoves in which air passes over heated surfaces are more economical than ordinary gas stoves, but, on the other hand, they are more liable to

cause unpleasant odours through the heating of the dust particles. With these stoves, as also with hot-air and hot-water pipes, as distinct from grates, the heated air has a great tendency to rise to the top of the room, leaving the feet cold while the head is too warm. The same effect is noticed where enclosed stoves are set forward some distance into the room, but these stoves are very economical, and where fuel is dear this is a paramount consideration. One pound of coal burnt in an ordinary grate requires, for its proper combustion, 300 cubic feet of air having a temperature of 620° Fahrenheit, and 1 volume of gas for complete combustion requires 5½ volumes of air. In atmospheric or Bunsen burners the average mixture of gas and air is 1 volume of gas to 2.3 volumes of air, consequently, a further supply of air around the flame is necessary to cause complete combustion, and an analysis of the gases, taken from the centre of the glowing fuel, shows that often 10 per cent of carbon monoxide exists, and, should down-draughts occur, this must find its way unnoticed—for it has neither smell nor color—into the room, hence the necessity for ensuring a good draught from the stove. Curiously enough, however, the analyses of gases in the flue during the burning of the gas stove do not show a trace of this deadly gas. An average of some twenty-four stoves tested in this way showed the presence of 12 per cent of oxygen, 84 per cent of

nitrogen, and 4 per cent of carbonic acid, thus proving that all the carbon monoxide had been converted into carbonic acid before leaving the stove when burning in the proper manner. This shows conclusively that flues are a necessity with gas stoves in which Bunsen burners are in use, although they need not be so large as the usual coal-grate flue, but where flues are not possible, only such stoves as employ ordinary lighting burners and utilise the heat radiated from a polished surface should be fixed.

Where a smoky chimney exists, a gas stove will not cure it, unless the fault is due to a contraction of the flue, by which the flow of the draught is impeded. In that case a much smaller flue for carrying off the products of combustion being sufficient with a gas stove as compared with a coal fire, the trouble will probably disappear, but it would be well to ascertain the origin of the fault before recommending the adoption of a gas stove as a remedy.

GAS-FITTING IN WORKSHOPS.

In fitting workshops with gas, it is important that strong materials be employed and it is desirable to use iron pipes throughout. Where a row of benches is fixed upon each side of a workshop, it is usual to run a pipe along just below the ceiling, with tees between each window, from these a small pipe is carried down to either a single or double swing iron bracket. Some firms who make gas-fittings, supply iron brackets, but they can be made up quickly from the fittings and short pieces of iron pipe. Brass swivels wear considerably better than those that are made of iron, and do not corrode and stick in the working parts.

When the lights are to be located down the middle of a workshop where lathes or other machine tools are used, the only brass parts are the cocks and burner elbows, the ordinary iron tee being very suitable for the centre of the pendant. Where more than one floor is to be lighted, fix on the supply pipe a governor for regulating the quantity of gas delivered, otherwise the pressure due to the height of the upper floors will cause a lowering of the light in the ground floor or basement. It is also an advantage to have each floor separate-

ly supplied from the main, so that each floor may be shut off entirely without interfering with the others, and if a separate meter be supplied for each floor, the quantity of gas consumed in proportion to the work done after dark may be checked, and any escape noted. Where a pipe falls, a pipe syphon or syphon-box should be fixed, as the temperature is subject to extreme changes and the quantity of condensation is much greater than in private houses.

When the pipes are run through the floor and up the legs of the lathes or other machinery, it is usual to bend the pipe to the exact curves taken by the machine, and to fix the pipe in its place by means of bands of iron bent to the curve of the pipe, and fixed to the machine by two small set screws. These bands may also be found useful in fitting up houses where the nature of the wall or floor will not permit the use of the ordinary pipe-hook.

It is often found necessary to fit up in a workshop over each machine a bracket arranged so as to move in any direction to suit the convenience of the workman. One way of making these fittings is to make the elbows of the brackets of two double swing swivels—one upright and one on its side. Another way is to have two lines of pipes from the support, and to connect both at each end to double swivels, while between the upper and lower pipe, and laid at an angle, is a thin bar,

which is fixed on to the upper pipe, and can be clamped to the lower one when the exact position required has been obtained. This form of bracket is useful in drawing offices, where the burner and shade commonly in use cause the other pattern of bracket to gradually fall downwards on to the table, whereas the second arrangement always keeps parallel, and, if tightly clamped, cannot change its position without breaking the thin metal bar, which should be made sufficiently strong to withstand the strain due to the weight of the heaviest burner chimney and shade likely to be placed upon it.

In making brackets and pendants it is convenient to know a quick and efficient way to bend iron pipes. The exact shape required having been drawn full size upon paper the latter is tacked or posted on to a rough board. Strong cut nails are then driven in it to follow the desired curve, the nails being half the outside diameter of the pipe from the drawn line, so that the centre of the pipe, when bent, may lie directly over the drawn line. The iron pipe is heated in a forge fire or in a furnace, the latter heats the pipe equally over the length required. The end is inserted between the lines of nails, and, with the aid of a pair of pliers, is quickly made to follow the curves indicated by the nails. Nails are not necessary on the outer side of the curves, except at the starting point, where a firm grip of the pipe must be insured.

Where many pipes are to be bent to the same shape, the board is replaced by a square plate, with holes all over it, cast or wrought-iron curves replacing the nails. The saving in time and the accuracy of the bending soon repay the additional outlay. In bending iron pipe, proceed gradually, and make only small curves at a time, or the pipe will collapse.

For shop brackets, metal backs are found suitable. These metal backs are supplied with the fittings, and are drilled and countersunk ready for erection, space being left for the pipe to screw into the top of the swivel joint. A metal back makes a strong job, and answers every purpose where very neat finish is not necessary.

In all workshops ventilation is a prime requisite, and must be provided for, more especially where the rooms are low and a considerable number of workmen and gas lights are employed. Gas is an excellent draught inductor, an ordinary batwing or union jet burner consuming 1 cubic foot of gas per hour, when placed in a six-inch ventilating tube 12 feet long, will cause 2,460 cubic feet of air per hour to pass up the tube, and this induced draught can be easily adapted for the removal of the heated and vitiated air from the upper portion of the room. Each person present will give off per hour about 17.7 cubic feet of air, of which from .6 to .8 of a cubic foot will be carbonic acid (CO_2), the amount of CO_2 evolved from the com-

bustion of coal gas is equal practically to one-half the quantity of gas burnt, and an ordinary gas burner may be considered as being equivalent to at least three adults in its effect upon the atmosphere. The air space required in a workshop is 250 cubic feet for each person during the day and 400 feet at night. Again, 500 cubic feet of fresh air per person should be delivered into a room during each hour, and therefore the same quantity of vitiated air must be drawn away by some means, no method is more suitable or so effective as the one above proposed, in which a lighted gas burner is enclosed by a ventilating shaft. A well-constructed ceiling burner has an excellent effect upon the ventilation of a room, workshop, or hall, when a properly arranged vertical shaft, usually of sheet iron, is carried up through the roof, and will at the same time assist greatly in the general illumination of the shop.

USEFUL INFORMATION.

One heaped bushel of anthracite coal weighs from 75 to 80 lbs.

One heaped bushel of bituminous coal weighs from 70 to 75 lbs.

One bushel of coke weighs 32 lbs.

Water, gas and steam pipes are measured on the inside.

One cubic inch of water evaporated at atmospheric pressure makes 1 cubic foot of steam.

A heat unit known as a British Thermal Unit raises the temperature of 1 pound of water 1 degree Fahrenheit.

For low pressure heating purposes, from 3 to 8 pounds of coal per hour is considered economical consumption, for each square foot of grate surface in a boiler, dependent upon conditions.

A horse power is estimated equal to 75 to 100 square feet of direct radiation. A horse power is also estimated as 15 square feet of heating surface in a standard tubular boiler.

Water boils in a vacuum at 98 degrees Fahrenheit.

A cubic foot of water weighs 62½ pounds, it contains 1,728 cubic inches or 7½ gallons. Water

expands in boiling about one-twentieth of its bulk.

In turning into steam water expands 1,700 its bulk, approximately 1 cubic inch of water will produce 1 cubic foot of steam.

One pound of air contains 13.82 cubic feet.

It requires 1½ British Thermal Units to raise one cubic foot of air from zero to 70 degrees Fahrenheit.

At atmospheric pressure 966 heat units are required to evaporate one pound of water into steam.

A pound of anthracite coal contains 14,500 heat uits.

One horsepower is equivalent to 42.75 heat units per minute.

One horsepower is required to raise 33,000 pounds one foot high in one minute.

To produce one horsepower requires the evaporation of 2.66 pounds of water.

One ton of anthracite coal contains about 40 cubic feet.

One bushel of anthracite coal weighs about 86 pounds.

Heated air and water rise because their particles are more expanded, and therefore lighter than the colder particles.

A vacuum is a portion of space from which the air has been entirely exhausted.

Evaporation is the slow passage of a liquid into the form of vapor.

Increase of temperature, increased exposure of surface, and the passage of air currents over the surface, cause increased evaporation.

Condensation is the passage of a vapor into the liquid state, and is the reverse of evaporation.

Pressure exerted upon a liquid is transmitted undiminished in all directions, and acts with the same force on all surfaces, and at right angles to those surfaces.

The pressure at each level of a liquid is proportional to its depth.

With different liquids and the same depth, pressure is proportional to the density of the liquid.

The pressure is the same at all points on any given level of a liquid.

The pressure of the upper layers of a body of liquid on the lower layers causes the latter to exert an equal reactive upward force. This force is called buoyancy.

Friction does not depend in the least on the pressure of the liquid upon the surface over which it is flowing.

Friction is proportional to the area of the surface.

At a low velocity friction increases with the velocity of the liquid.

Friction increases with the roughness of the surface.

Friction increases with the density of the liquid.

Friction is greater comparatively, in small

pipes, for a greater proportion of the water comes in contact with the sides of the pipe than in the case of the large pipe. For this reason mains on heating apparatus should be generous in size.

Air is extremely compressible, while water is almost incompressible.

Water is composed of two parts of hydrogen, and one part of oxygen.

Water will absorb gases, and to the greatest extent when the pressure of the gas upon the water is greatest, and when the temperature is the lowest, for the elastic force of gas is then less.

Air is composed of about one-fifth oxygen and four-fifths nitrogen, with a small amount of carbonic acid gas.

To reduce Centigrade temperatures to Fahrenheit, multiply the Centigrade degrees by 9, divide the result by 5, and add 32.

To reduce Fahrenheit temperature to Centigrade, subtract 32 from the Fahrenheit degrees, multiply by 5 and divide by 9.

To find the area of a required pipe, when the volume and velocity of the water are given, multiply the number of cubic feet of water by 144 and divide this amount by the velocity in feet per minute.

Water boils in an open vessel (atmospheric pressure at sea level) at 212 degrees Fahrenheit.

Water expands in heating from 39 to 212 degrees Fahrenheit, about 4 per cent.

Water expands about one-tenth its bulk by freezing solid.

Water is at its greatest density and occupies the least space at 39 degrees Fahrenheit.

Water is the best known absorbent of heat, consequently a good vehicle for conveying and transmitting heat.

A U. S. gallon of water contains 231 cubic inches and weighs 8 1/3 pounds.

A column of water 27.67 inches high has a pressure of 1 pound to the square inch at the bottom.

Doubling the diameter of a pipe increases its capacity four times.

A hot water boiler will consume from 3 to 8 pounds of coal per hour per square foot of grate, the difference depending upon conditions of draft, fuel, system and management.

A cubic foot of anthracite coal averages 50 pounds. A cubic foot of bituminous coal weighs 40 pounds.

PRESSURE OF WATER FOR EACH FOOT IN HEIGHT.

Feet in Height.	Pounds per Sq. In.	Feet in Height.	Pounds per Sq. In.	Feet in Height.	Pounds per Sq. In.
1	.43	15	6.49	50	21.65
2	.86	20	8.66	70	30.32
5	2.16	25	10.82	80	34.65
10	4.33	40	17.32	100	43.31

BOILING POINTS OF VARIOUS FLUIDS.

Substance.	Degrees.	Substance.	Degrees.
Water in Vacuum	98	Refined Petroleum	316
Water, Atmosph'c Pres.	212	Turpentine	315
Alcohol	173	Sulphur	570
Sulphuric Acid	240	Linseed Oil	597

Weights.

One cubic inch of water weighs ..... 0.036 pounds
One U. S. gallon weighs... 8.33 "
One Imperial gallon " ... 10.00 "
One U. S. gallon equals....231.00 cubic inches
One Imperial gallon " ...277.274 " "
One cubic foot of water equals ..... 7.48 U. S. gallons

Liquid Measure.

4 Gills make 1 Pint
2 Pints make 1 Quart
4 Quarts make 1 Gallon
31½ Gals. make 1 Barrel

Size of Pipe in Inches.	Sq. Ft. in one Lineal Ft.	Gallons of Water in 100 Feet in Length.
¾	.27	2.77
1	.34	4.50
1¼	.43	7.75
1½	.50	10.59
2	.62	17.43
2½	.75	24.80
3	.92	38.38
3½	1.05	51.36
4	1.17	66.18

To find the area of a rectangle, multiply the length by the breadth.

To find the area of triangle, multiply the base by one-half the perpendicular height.

To find the circumference of a circle, multiply the diameter by 3.1416.

To find the area of a circle, multiply the diameter by itself, and the result by .7854.

To find the diameter of a circle of a given area, divide the area by .7854, and find the square root of the result.

To find the diameter of a circle which shall have the same area as a given square, multiply one side of the square by 1.128.

To find the number of gallons in a cylindrical tank, multiply the diameter in inches by itself, this by the height in inches, and the result by .34. To find the number of gallons in a rectangular tank, multiply together the length, breadth and height in feet, and this result by 7.4. If the dimensions are in inches, multiply the product by .004329. To find the pressure in pounds per square inch, of a column of water, multiply the height of the column in feet by .434.

To find the head in feet, the pressure being known, multiply the pressure per square inch by 2.31.

To find the lateral pressure of water upon the side of a tank, multiply in inches, the area of the

submerged side, by the pressure due to one-half the depth.

Example—Suppose a tank to be 12 feet long and 12 feet deep. Find the pressure on the side of the tank.

144 x 144=20,736 square inches area of side.

12 x .43=5.16, pressure at bottom of tank. Pressure at the top of tank is 0. Average pressure will then be 2.6. Therefore 20,736 x 2.6=53,914 pounds pressure on side of tank.

To find the number of gallons in a foot of pipe of any given diameter, multiply the square of diameter of the pipe in inches, by .0408.

To find the diameter of pipe to discharge a given volume of water per minute in cubic feet, multiply the square of the quantity in cubic feet per minute by 96. This will give the diameter in inches.

Cleaning Rusted Iron. Place the articles to be cleaned in a saturated solution of chloride of tin and allow them to stand for a half day or more.

When removed, wash the articles in water, then in ammonia. Dry quickly, rubbing them hard.

Removing Boiler Scale. Kerosene oil will accomplish this purpose, often better than specially prepared compounds.

Cleaning Brass. Mix in a stone jar one part of nitric acid, one-half part of sulphuric acid. Dip the brass work into this mixture, wash it off with water, and dry with sawdust. If greasy, dip the

work into a strong mixture of potash, soda, and water, to remove the grease. and wash it off with water.

Removing Grease Stains from Marble. Mix 1½ parts of soft soap, 3 parts of Fuller's earth and 1½ parts of potash, with boiling water. Cover the grease spots with this mixture, and allow it to stand a few hours.

Strong Cement. Melt over a slow fire, equal parts of rubber and pitch. When wishing to apply the cement, melt and spread it on a strip of strong cotton cloth.

Cementing Iron and Stone. Mix 10 parts of fine iron filings, 30 parts of plaster of Paris, and one-half parts of sal ammoniac, with weak vinegar. Work this mixture into a paste, and apply quickly.

Cement for Steam Boilers. Four parts of red or white lead mixed in oil, and 3 parts of iron borings, make a good soft cement for this purpose.

Cement for Leaky Boilers. Mix 1 part of powdered litharge, 1 part of fine sand, and one-half part of slacked lime with linseed oil, and apply quickly as possible.

Making Tight Steam Joints. With white lead ground in oil mix as much manganese as possible, with a small amount of litharge. Dust the board with red lead, and knead this mass by hand into a small roll, which is then laid on the plate, oiled

with linseed oil. It can then be screwed into place.

Substitute for Fire Clay. Mix common earth with weak salt water.

Rust Joint Cement. Mix 5 pounds of iron filings, 1 ounce of sal ammoniac, and 1 ounce of sulphur, and thin the mixture with water.

Removing Rust from Steel. Mix one-half ounce of cyannide of potassium, ½ ounce of castile soap, 1 ounce of whiting, adding enough water to form a paste, and apply to the steel. Rinse it off with a solution formed of one-half ounce of cyannide of potassium and 2 ounces of water.

COMPARATIVE VALUE OF COAL, OIL, AND GAS.

In good practice, with boilers of proper construction and proportioned to the work—

One pound of coal will evaporate 10 pounds of water at 212 degrees Fahrenheit.

One pound of oil will evaporate 16 pounds of water at 212 degrees Fahrenheit.

One pound of natural gas will evaporate 20 pounds of water at 212 degrees Fahrenheit.

One pound of coal equals 11.225 cubic feet of natural gas.

Two thousand pounds of coal (1 ton) equals 22,450 cubic feet of natural gas.

One pound of oil equals 18.00 cubic feet of natural gas.

One barrel of oil (42 gallons) equals 5,310.00 cubic feet of natural gas.

1.125 cubic feet of natural gas will evaporate 1 pound of water.

1.00 cubic feet of natural gas equals 860 Heat Units.

1,000 cubic feet of natural gas equals 860,000 Heat Units.

One ton of coal will equal 19,307,000 Heat Units.

One barrel of oil will equal 4,566.600 Heat Units.

In ordinary practice, about twice as much of the above fuels are required to evaporate the above amounts.

USEFUL KINKS.

Paint for Iron. Dissolve ½ pound of asphaltum and ½ pound of pounded resin in 2 pounds of tar oil. Mix hot in an iron kettle, but do not allow it to come in contact with the fire. It may be used as soon as cold, and is good both for outdoor wood and ironwork.

Recipe for Heat-Proof Paint. A good cylinder and exhaust pipe paint is made as follows:

Two pounds of black oxide of manganese, 3 pounds of graphite and 9 pounds of Fuller's earth, thoroughly mixed. Add a compound of 10 parts of sodium silicate, 1 part of glucose and 4 parts of water, until the consistency is such that it can be applied with a brush.

Rust Joint Composition. This is a cement made of sal-ammoniac 1 pound, sulphur ½ pound, cast-iron turnings 100 pounds. The whole should be thoroughly mixed and moistened with a little water. If the joint is required to set very quick, add ¼ pound more sal-ammoniac. Care should be taken not to use too much sal-ammoniac, or the mixture will become rotten.

Removing Rust from Iron. Iron may be quickly and easily cleaned by dipping in or

washing with nitric acid one part, muriatic acid one part and water twelve parts. After using wash with clean water.

Making Pipe Joints. Never screw pipe together for either steam, water or gas without putting white or red lead on the joints.

Many times in taking pipe apart the joints are stuck so hard that it is impossible to unscrew the pipe; heat the coupling (not the pipe) by holding a hot iron on it, or hammer the coupling with a light hammer, either one will expand the coupling and break the joint so it can be easily unscrewed.

Annealing Cast Iron. To anneal cast iron, heat it in a slow charcoal fire to a dull red heat; then cover it over about two inches with fine charcoal, then cover all with ashes. Let it lay until cold. Hard cast iron can be softened enough in this way to be filed or drilled. This process will be exceedingly useful to iron founders, as by this means there will be a great saving of expense in making new patterns.

To make a casting of precisely the same size of a broken casting without the original patterns: Put the pieces of broken casting together and mould them, and cast from this mould. Then anneal it as above described; it will expand to the original size of the pattern, and there remain in that expanded state.

Preventing Iron or Steel from Rusting. The

best treatment for polished iron or steel, which has a habit of growing gray and lustreless, is to wash it very clean with a stiff brush and ammonia soapsuds, rinse well and dry by heat if possible, then oil plentifully with sweet oil and dust thickly with powdered quick lime. Let the lime stay on two days, then brush it off with a clean stiff brush. Polish with a softer brush, and rub with cloths until the lustre comes out. By leaving the lime on, iron and steel may be kept from rust almost indefinitely.

Loosening Rusted Screws. One of the simplest and readiest ways of loosening a rusted screw is to apply heat to the head of the screw. A small bar or rod of iron, flat at the end, if reddened in the fire and applied for two or three minutes to the head of a rusty screw, will, as soon as it heats the screw, render its withdrawal as easy with the screwdriver as if it were only a recently inserted screw. This is not particularly novel, but it is worth knowing.

Tinning Cast Iron. To successfully coat castings with tin they must be absolutely clean and free from sand and oxide. They are usually freed from imbedded sand in a rattler or tumbling box, which also tends to close the surface grain and give the article a smooth metallic face. The articles should be then placed in a hot pickle of one part of sulphuric acid to four parts of water, in which they are allowed to

remain from one to two hours, or until the recesses are free from scale and sand. Spots may be removed by a scraper or wire brush. The castings are then washed in hot water and kept in clean hot water until ready to dip. For a flux, dip in a mixture composed of four parts of a saturated solution of sal-ammoniac in water and one part of hydrochloric acid, hot. Then dry the castings and dip them in the tin pot. The tin should be hot enough to quickly bring the castings to its own temperature when perfectly fluid, but not hot enough to quickly oxidize the surface of the tin. A sprinkling of pulverized sal-ammoniac may be made on the surface of the tin, or a little tallow or palm oil may be used to clear the surface and make the tinned work come out clear. As soon as the tin on the castings has chilled or set, they should be washed in hot sal soda water and dried in sawdust.

Removing Scale from Iron Castings. Immerse the parts in a mixture composed of one part of oil of vitriol to three parts of water. In six to ten hours remove the castings, and wash them thoroughly with clean water. A weaker solution can be used by allowing a longer time for the action of the solution.

Cleaning Brass Castings. If greasy, the castings should be cleaned by boiling in lye or potash. The first pickle is composed of nitric acid one quart, water six to eight quarts. After

pickling in this mixture the castings should be washed in clear warm or hot water, and the following pickle be then used: Sulphuric acid one quart, nitric acid two quarts, muriatic acid, a few drops. The first pickle will remove the discolorations due to iron, if present. The muriatic acid of the second pickle will darken the color of the castings to an extent depending on the amount used.

Tinning Surfaces. Articles of brass or copper boiled in a solution of cyanide of potassium mixed with turnings or scraps of tin in a few moments become covered with a firmly attached layer of fine tin.

A similar effect is produced by boiling the articles with tin turnings or scraps and caustic alkali, or cream of tartar. In either way, articles made of copper or brass may be easily and perfectly tinned.

Protecting Bright Work from Rust. Use a mixture of one pound of lard, one ounce of gum camphor, melted together, with a little lampblack. A mixture of lard oil and kerosene in equal parts. A mixture of tallow and white lead, or of tallow and lime.

How to Braze. Clean the article thoroughly and better to polish with sand paper. Fasten the parts to be brazed firmly together, so they will not part when heated in the fire. Place over a slow fire of charcoal or well coked coal. Place

on the parts to be brazed a small quantity of pulverized borax; as soon as this is done boiling and has flowed to all parts, then put on the spelter; when the spelter melts it will generally run in globules or shot. Jar the piece by gently striking with a small piece of wire; this will cause the spelter to flow to all parts.

Lead Explosions. Many mechanics have had their patience sorely tried when pouring lead around a damp or wet joint, to have it explode, blow out or scatter from the effects of steam generated by the heat of the lead. The whole trouble may be avoided by putting a piece of resin, the size of a man's thumb, into the ladle and allowing it to melt before pouring.

Sharpening Files. To sharpen dull and worn out files, lay them in dilute Sulphuric Acid, one part acid to two parts of water over night, then rinse well in clear water, put the acid in an earthenware vessel.

Soldering Aluminum. When soldering aluminum, it should be borne in mind that upon exposure to the air a slight film of oxide forms over the surface of the aluminum, and afterwards protects the metal. The oxide is the same color as the metal, so that it cannot easily be distinguished. The idea in soldering is to get underneath this oxide while the surface is covered with the molten solder. Clean off all dirt and grease from the surface of the metal with a little

benzine, apply the solder with a copper bit, and when the molten solder is covering the surface of the metal, scratch through the solder with a steel wire scratch-brush. By this means the oxide on the surface of the metal is broken up underneath the solder, which containing its own flux, takes up the oxide and enables the surface of the aluminum to be tinned properly.

Small surfaces of aluminum can be soldered by the use of zinc and Venetian turpentine. Place the solder upon the metal together with the turpentine and heat very gently with a blowpipe until the solder is entirely melted. The trouble with this, as with other solders, is that it will not flow gently on the metal. Therefore large surfaces cannot be easily soldered.

Another method is to clean the aluminum surfaces by scraping, and then cover with a layer of paraffine wax as a flux. Then coat the surfaces by fusion, with a layer of an alloy of zinc, tin and lead, preferably in the following proportions; Zinc five parts, tin two parts, lead one part.

The metallic surfaces thus prepared can be soldered together either by means of zinc or cadmium, or alloys of aluminum with these metals. In fact, any good soldering preparation will answer the purpose.

A good solder for low-grade work is the following: Tin 95 parts, bismuth five parts.

A good flux in all cases is either stearin, vaseline, paraffine, copaiva balsam, or benzine.

In the operation of soldering, small tools made of aluminum are used, which facilitate at the same time the fusion of the solder and its adhesion to the previously prepared surfaces. Tools made of copper or brass must be strictly avoided as they would form colored alloys with the aluminum and the solder.

Aluminum Solder. This consists of 28 pounds of block tin, three and one-half pounds of lead, seven pounds of spelter, and 14 pounds of phosphor-tin. The phosphor-tin should contain 10 per cent of phosphorus. Clean off all the dirt and grease from the surface of the metal with benzine, apply the solder with a copper bit, and when the molten solder covers the metal, scratch through the solder with a wire scratch brush.

Sweating Aluminum to Other Metals. First coat the aluminum surface to be soldered with a layer of zinc. On top of the zinc is melted a layer of an alloy of one part aluminum to two and one-half parts of zinc. The surfaces are placed together and heated until the alloy between them is liquefied.

Soldering Fluid. Take of scrap zinc or pure spelter about ¼ pound, and immerse in a half-pint of muriatic acid. If the scraps completely dissolve add more until the acid ceases to bubble and a small piece of metal remains. Let this

stand for a day and then carefully pour off the clear liquid, or filter it through a cone of blotting paper. Add a teaspoonful of sal-ammoniac, and when thoroughly dissolved, the solution is ready for use. Depending on the materials to be soldered, the quantity of sal-ammoniac can be reduced. Its presence makes soldering very easy, but, unless the parts are well heated so as to evaporate the salt, the joints may rust.

Etching on Iron or Steel. Take one-half ounce of nitric acid and one ounce of muriatic acid. Mix, shake well together, and it is ready for use. Cover the place you wish to mark with melted beeswax, when cold write the inscription plainly in the wax clear to the metal with a sharp instrument, then apply the mixed acids with a feather, carefully filling each letter. Let it remain from one to ten minutes, according to the appearance desired. Then throw on water, which stops the etching process and removes the wax.

Soldering Solution. An excellent method of preparing resin for soldering bright tin is given as follows: Take one and one-half pounds of olive oil and one and one-half pounds of tallow and 12 ounces of pulverized resin. Mix these ingredients and let them boil up. When this mixture has become cool, add one and three-eighths pints of water saturated with pulverized sal ammoniac, stirring constantly.

Softening Cast Iron. To soften iron for drill-

ing, heat to a cherry-red, having it lie level in the fire. Then with tongs, put on a piece of brimstone, a little less in size than the hole is to be. This softens the iron entirely through. Let it lie in the fire until cooled, when it is ready to drill.

Suggestions how to Solder. Clean the parts thoroughly from all rust, grease or scale, then wet with prepared acid. Hold the soldering copper on each part until the article is well tinned and the solder has flowed to all parts.

Watch-Makers' Oil that Will Never Corrode or Thicken. Take a bottle about half full of good olive oil and put in thin strips of sheet lead, expose it to the sun for a month, then pour off the clear oil. The above is a very cheap way of making a first-class oil for any light machinery.

Varnish for Copper. To protect copper from oxidation a varnish may be employed which is composed of carbon disulphide 1 part, benzine 1 part, turpentine oil 1 part, methyl alchol 2 parts and hard copal 1 part. It is well to apply several coats of it to the copper.

Glue for Iron. Put an equal amount by weight of finely powdered rosin in glue and it will adhere firmly to iron or other metal surfaces.

Soldering or Tinning Acid. Muriatic Acid 1 pound, put into it all the zinc it will dissolve and 1 ounce of Sal Ammoniac, add as much clear water as acid, it is then ready for use.

Plaster of Paris. Common plaster that farmers

use to put on land and plaster of paris are the same thing, except plaster of paris is common plaster calcined. Many times it is difficult to get calcined plaster, and when it is procured it is badly adulterated with lime and unfit for many uses. To calcine plaster, or in other words, to make common plaster so it will harden, you have but to take the plaster and put it in an iron kettle and place it over a slow fire, put no water in it. In a few moments it will begin to boil and will continue to do so until every particle of moisture is evaporated out of it. When it has stopped boiling take it off, and when cold it is ready for use. Plaster treated in this way will harden much quicker and harder than any which can be bought ready prepared.

Hardening Small Articles. To harden small tools or articles that are apt to warp in hardening, heat very carefully, and insert in a raw potato, then draw the temper as usual.

Bluing Brass. Dissolve one ounce of antimony chloride in twenty ounces of water and add three ounces of pure hydrochloric acid. Place the warmed brass article into this solution until it has turned blue. Then wash it and dry in sawdust.

Drilling Glass. Take an old three-cornered file, one that is worn out will do, break it off and sharpen to a point like a drill and place in a carpenter's brace. Have the glass fastened on a

good solid table so there will be no danger of its breaking. Wet the glass at the point where the hole is to made with the following solution:

Ammonia .....6½ drachms
Ether .....3½ drachms
Turpentine .....1 ounce

Keep the drill wet with the above solution and bore the hole part way from each side of the glass.

Another solution is to dissolve a piece of gum camphor the size of a walnut in one ounce of turpentine.

Another method is to use a steel drill hardened, but not drawn. Saturate spirits of turpentine with camphor and wet the drill. The drill should be ground with a long point and plenty of clearance. Run the drill fast and with a light feed. In this manner glass can be drilled with small holes, up to 3-16 inch in diameter nearly as rapidly as cast steel.

Cement for Pipe Joints. Mix 10 parts iron filings and 3 parts chloride of lime to a paste by means of water. Apply to the joint and clamp up. It will be solid in 12 hours.

Removing Stains. To remove Ink Stains, wash with pure fresh water, and apply oxalic acid. If this changes the stain to a red color, apply ammonia. To remove Iron Rust from White Fabrics, saturate the spots with lemon juice and salt and expose to the sun.

Weight of Castings. If you have a pattern made of soft pine, put together without nails, an iron casting made from it will weigh sixteen pounds to every pound of the pattern. If the casting is of brass, it will weigh eighteen pounds to every pound of the pattern.

Ordering Taps and Dies. In ordering Taps and Dies, be sure and give the kind, exact size and thread wanted. Always remember you are writing to a person who knows nothing of what is wanted, therefore make the order plain and explicit. Never order a special Tap or Die if it can be avoided, as such will cost at least double that of regular sizes and threads.

Tapping Nuts. Always use good Lard Oil in cutting threads with a die or tapping out nuts. Poor cheap oil will soon ruin both die and tap.

Grindstones. Grindstones to grind tools should be run at a speed of about 800 feet per minute at its periphery, a 30-inch stone should be run about 100 revolutions per minute. When used to grind carpenters' tools a speed of 600 feet at its periphery, a 30-inch stone should therefore be run at 75 revolutions per minute.

White Metal for Bearings. White metal for bearings consists of 48 pounds of tin, 4 pounds of copper, and 1 pound of antimony. The copper and tin are melted first, and then the antimony is added.

Marine Glue. One part of pure india rubber

dissolved in naphtha. When melted add two parts of shellac. Melt until mixed.

To Soften Cast Iron. Heat the whole piece to a bright glow and gradually cool under a covering of fine coal dust. Small objects should be packed in quantities, in a crucible in a furnace or open fire, under materials which when heated to a glow give out carbon to the iron. They should be heated gradually, and kept at a bright heat for an hour and allowed to cool slowly. The substances recommended to be added are cast-iron turnings, sodium carbonate or raw sugar. If only raw sugar is used, the quantity should not be too small. By this process it is said that cast iron may be made so soft that it can almost be cut with a pocket-knife.

To Harden Files. To harden files dip the file in redhot lead, handle up. This gives a uniform heat and prevents warping. Run the file endwise back and forth in a pan of salt water. Set the file in a vise and straighten it while still warm.

Leather Belts. A leather belt is more economical in the end than a rubber one. When buying a leather belt it should be tested by doubling it up with the hair side out. If it should crack, reject it as it cannot realize the whole amount of power it should transmit. If it shows a spongy appearance it should be condemned at once, for it must be pliable as well as firm. The grain or hair side should be free from wrinkles and the

belt should be of uniform thickness throughout its length. It should be tested for quality by immersing a small strip in strong vinegar. If the leather has been properly tanned and is of good quality, it will remain in vinegar for weeks without alteration, excepting it will grow darker in color. If the leather has not been properly tanned the fiber will swell and the leather will become softened, turning it into a jelly-like mass.

To Cement Rubber to Leather. Roughen both surfaces with a sharp piece of glass, apply on both a diluted solution of gutta percha in carbon bisulphide, and let the solution soak into the material. Then press upon each surface a skin of gutta percha about one-hundredth of an inch in thickness, between a pair of rolls. Unite the two surfaces in a press that should be warm but not hot. In case a press cannot be used, dissolve 30 parts of rubber in 140 parts of carbon bisulphide, the vessel being placed on a water bath of a temperature of 86 degrees Fahrenheit. Melt ten parts of rubber with fifteen parts of rosin and add 35 parts of oil of turpentine. When the rubber has been completely dissolved, the two liquids may be mixed. The resulting cement must be kept well corked.

Drilling Holes in Glass. Holes of any size desired may be drilled in glass by the following method: Get a small 3-cornered file and grind the points from one corner and the bias from

the other and set the file in a brace, such as is used in boring wood. Lay the glass in which the holes are to be bored on a smooth surface covered with a blanket and begin to bore a hole. When a slight impression is made on the glass, place a disk of putty around it and fill with turpentine to prevent too great heating by friction. Continue boring the hole, which will be as smooth as one drilled in wood with an auger. Do not press too hard on the brace while drilling.

To Polish Brass. Smooth the brass with a fine file and run it with smooth fine grain stone, or with charcoal and water. When quite smooth and free from scratches, polish with pumice stone and oil, spirits of turpentine, or alcohol.

How to Make a Soft Alloy. A soft alloy which will adhere tenaciously to metal, glass or porcelain, and can also be used as a solder for articles which cannot bear a high degree of heat, is made as follows:

Obtain copper-dust by precipitating copper from the sulphate by means of metallic zinc. Place from 20 to 36 parts of the copper-dust, according to the hardness desired, in a porcelain-lined mortar, and mix well with some sulphuric acid of a specific gravity of 1.85. Add to this paste 70 parts of mercury, stirring constantly, and when thoroughly mixed, rinse the amalgam in warm water to remove the acid. Let cool from 10 to

12 hours, after which time it will be hard enough to scratch tin.

When ready to use it, heat to 707 degrees Fahrenheit and knead in an iron mortar till plastic. It can then be spread on any surface, and when it has cooled and hardened will adhere most tenaciously.

MEDICAL AID.

Things to Do in Case of Sprains or Dislocations. The most important thing is to secure rest until the arrival of the surgeon. If the sprain is in the ankle or foot, place a folded towel around the part and cover with a bandage. Apply moist heat. The foot should be immersed in a bucket of hot water and more hot water added from time to time, so that it can be kept as hot as can be borne for fifteen or twenty minutes, after which a firm bandage should be aplied, by a surgeon, if possible, and the foot elevated.

In sprains of the wrist, a straight piece of wood should be used as a splint, cover with cotton or wool to make it soft, and lightly bandage, and carry the arm in a sling. In all cases of sprains the results may be serious, and a surgeon should be obtained as soon as possible. After the acute symptoms of pain and swelling have subsided, it is still necessary that the joint should have complete rest by the use of a splint and bandage and such applications as the surgeon may direct.

Simple dislocation of the fingers can be put in place by strong pulling, aided by a little pressure on the part of the bones nearest the joint.

The best that can be done in most cases is to

put the part in the position easiest to the sufferer, and to apply cold wet cloths, while awaiting the arrival of a surgeon.

To Remove Foreign Substances from the Eye. Take hold of the upper lid and turn it up so that the inside of the upper lid may be seen. Have the patient make several movements with the eye, first up, then down, to the right side and to the left. Then take a tooth-pick with a little piece of absorbent cotton wound around the end and moistened in cold water, and swab it out. The foreign substance will adhere to the swab and the object will be removed from the eye without any trouble.

In Case of Cuts. The chief points to be attended to are: Arrest the bleeding. Remove from the wound all foreign substances as soon as possible. Bring the wounded parts opposite to each other and keep them so. This is best done by means of strips of surgeon's plaster, first applied to one side of the wound and then secured to the other. These strips should not be too broad, and space must be left between the strips to allow any matter to escape. Wounds too extensive to be held together by plaster must be stitched by a surgeon, who should always be sent for in severe cases.

Broken Limbs. To get at a broken limb or rib, the clothing must be removed, and it is essential that this should be done without injury to the patient. The simplest plan is to rip up the seams

of such garments as are in the way. Shoes must always be cut off. It is not imperatively necessary to do anything to a broken limb before the arrival of a doctor, except to keep it perfectly at rest.

Wounds. If a wound be discovered in a part covered by the clothing, cut the clothing at the seams. Remove only sufficient clothing to uncover and inspect the wound.

All wounds should be covered and dressed as quickly as possible. If a severe bleeding should occur, see that this is stopped, if possible, before the wound is dressed.

Treatment of Burns. In treating burns of a serious nature, the first thing to be done after the fire is extinguished should be to remove the clothing. The greatest care must be exercised, as anything like pulling will bring the skin away. If the clothing is not thoroughly wet, be sure to saturate it with water or oil before attempting to remove it.

If portions of the clothing will not drop off, allow them to remain. Then make a thick solution of common baking soda and water, and dip soft cloths in it and lay them over the injured parts, and bandage them lightly to keep them in position. Have the solution near by, and the instant any part of a cloth shows signs of dryness, squeeze some of the solution on that part. Do not remove the cloth, as total exclusion of the

air is necessary, and little, if any, pain, will be felt as long as the cloths are kept saturated. This may be kept up for several days, after which soft cloths dipped in oil may be applied, and covered with cotton batting. If the feet are cold, apply heat and give hot water to drink, and if the burns are very serious send for a doctor as soon as possible. The presence of pain is a good sign, showing that vitality is present.

Bleeding. In case of bleeding, the person may become weak and faint, unless the blood is flowing actively. This is not a serious sign, and the quiet condition of the faint often assists nature in stopping the bleeding, by allowing the blood to clot and so block up any wound in a blood vessel.

Unless the faint is prolonged or the patient is losing much blood, it is better not to relieve the faint condition. When in this state excitement should be avoided, and external warmth should be applied, the person covered with blankets, and bottles of hot water or hot bricks applied to the feet and arm-pits.

Watch carefully if unconscious.

If vomiting occurs, turn the patient's body on one side, with the head low, so that the matters vomited may not go into the lungs.

Bleeding is of three kinds: From the arteries which lead from the heart. That which comes from the veins which take the blood back to the heart. That from the small veins which carry

the blood to the surface of the body. In the first, the blood is bright scarlet and escapes as though it were being pumped. In the second, the blood is dark red and flows away in an uninterrupted stream. In the third, the blood oozes out. In some wounds all three kinds of bleeding occur at the same time.

Carrying an Injured Person. In case of an injury where walking is impossible, and lying down is not absolutely necessary, the injured person may be seated in a chair, and carried, or he may sit upon a board, the ends of which are carried by two men, around whose necks they should place his arms so as to steady himself.

Where an injured person can walk he will get much help by putting his arms over the shoulders and round the necks of two others.

Lap-Welded Steel or Charcoal Iron Boiler Tubes.

Table of Standard Dimensions.

Diameter.		Nominal Thickness.	Wire Gauge.	Circumference.		Transverse Areas.			Length of Tube per Square Foot of		Nominal Weight per Foot.
External	Internal			External	Internal	External	Internal	Metal.	External Surface.	Internal Surface.	
Inches.	Inches.	Inches.	No.	Inches.	Inches.	Sq. In.	Sq. In.	Sq. In.	Feet.	Feet.	Pounds.
1	.856	.095	13	3.142	2.689	.785	.575	.21	3.819	4.462	.90
1¼	1.106	.095	13	3.927	3.475	1.227	.961	.266	3.056	3.453	1.15
1½	1.334	.095	13	4.712	4.191	1.767	1.398	.369	2.547	2.863	1.40
1¾	1.56	.095	13	5.494	4.901	2.405	1.911	.494	2.183	2.448	1.66
2	1.81	.095	13	6.283	5.686	3.142	2.573	.569	1.909	2.11	1.91
2¼	2.06	.095	13	7.069	6.472	3.976	3.333	.648	1.698	1.854	2.16
2½	2.282	.109	12	7.854	7.169	4.909	4.09	.819	1.528	1.674	2.75
2¾	2.532	.109	12	8.639	7.954	5.94	5.035	.905	1.389	1.509	3.04
3	2.782	.109	12	9.425	8.74	7.069	6.079	.99	1.273	1.373	3.33
3¼	3.01	.12	11	10.21	9.456	8.296	7.116	1.18	1.175	1.26	3.96
3½	3.26	.12	11	10.996	10.241	9.621	8.347	1.274	1.091	1.172	4.28
3¾	3.51	.12	11	11.781	11.027	11.045	9.676	1.369	1.018	1.088	4.6
4	3.732	.134	10	12.566	11.724	12.566	10.939	1.627	.955	1.024	5.47
4½	4.232	.134	10	14.137	13.295	15.804	14.066	1.838	.849	.902	6.17
5	4.704	.148	9	15.708	14.778	19.635	17.379	2.256	.764	.812	7.58

Wrought Iron and Steel Steam, Gas and Water Pipe.

Table of Standard Dimensions.

Diameter.			Nominal Thickness.	Circumference.		Transverse Areas.			Length of Pipe per Square Foot of		Length of Pipe Containing One Cubic Foot.	Nominal Weight per Foot.	Number of Threads per Inch of Screw.
Nominal Internal	Actual External.	Approximate Internal Diameter.		External.	Internal.	External.	Internal.	Metal.	External Surface.	Internal Surface.			
Inch.	Inches.	Inches.	Inch.	Inches.	Inches.	Sq. In.	Sq. In.	Sq. In.	Feet.	Feet.	Feet.	Pounds	
1/8	.405	.27	.068	1.272	.848	.129	.0573	.0717	9.44	14.15	2513.	.241	27
1/4	.54	.364	.088	1.696	1.144	.229	.1041	.1249	7.075	10.49	1383.3	.42	18
3/8	.675	.494	.091	2.121	1.552	.358	.1917	.1663	5.657	7.73	751.2	.559	18
1/2	.84	.623	.109	2.639	1.957	.554	.3048	.2492	4.547	6.13	472.4	.837	14
3/4	1.05	.824	.113	3.299	2.589	.866	.5333	.3327	3.637	4.635	270.	1.115	14
1	1.315	1.048	.134	4.131	3.292	1.358	.8626	.4954	2.904	3.645	166.9	1.668	11½
1¼	1.66	1.38	.14	5.215	4.335	2.164	1.496	.668	2.301	2.768	96.25	2.244	11½
1½	1.9	1.611	.145	5.969	5.061	2.835	2.038	.797	2.01	2.371	70.66	2.678	11½
2	2.375	2.067	.154	7.461	6.494	4.43	3.356	1.074	1.608	1.848	42.91	3.609	11½
2½	2.875	2.468	.204	9.032	7.753	6.492	4.784	1.708	1.328	1.547	30.1	5.739	8
3	3.5	3.067	.217	10.996	9.636	9.621	7.388	2.243	1.091	1.245	19.5	7.536	8

Wrought Iron and Steel Steam, Gas and Water Pipe.

Table of Standard Dimensions.

Diameter.			Nominal Thickness.	Circumference.		Transverse Areas.			Length of Pipe per Square Foot of		Length of Pipe Containing One Cubic Foot.	Nominal Weight per Foot.	Number of Threads per Inch of Screw.
Nominal Internal	Actual External.	Approximate Internal Diameter.		External.	Internal.	External.	Internal.	Metal.	External Surface.	Internal Surface.			
Inch.	Inches.	Inches.	Inch.	Inches.	Inches.	Sq. In.	Sq. In.	Sq. In.	Feet.	Feet.	Feet.	Pounds.	
3½	4.	3.548	.226	12.566	11.146	12.566	9.887	2.679	.955	1.077	14.57	9.001	8
4	4.5	4.026	.237	14.137	12.648	15.904	12.73	3.174	.849	.949	11.31	10.665	8
4½	5.	4.508	.246	15.708	14.162	19.635	15.961	3.674	.764	.848	9.02	12.49	8
5	5.563	5.045	.259	17.477	15.849	24.306	19.99	4.316	.687	.757	7.2	14.502	8
6	6.625	6.065	.28	20.813	19.054	34.472	28.888	5.584	.577	.63	4.98	18.762	8
7	7.625	7.023	.301	23.955	22.063	45.664	38.738	6.926	.501	.544	3.72	23.271	8
8	8.625	7.982	.322	27.096	25.076	58.426	50.04	8.386	.443	.478	2.88	28.177	8
9	9.625	8.937	.344	30.238	28.076	72.76	62.73	10.03	.397	.427	2.29	33.701	8
10	10.75	10.019	.366	33.772	31.477	90.763	78.839	11.924	.355	.382	1.82	40.065	8
11	11.75	11.		36.914	34.558	108.434	95.033	13.401	.325	.347	1.51	45.028	8
12	12.75	12.		40.055	37.7	127.677	113.098	14.579	.299	.319	1.27	48.985	8

Wrought Iron and Steel Extra Strong Pipe.

Table of Standard Dimensions.

Diameter.			Nominal Thickness.	Nearest Wire Gauge.	Circumference.		Transverse Areas.			Length of Pipe per Square Foot of		Nominal Weight per Foot.
Nominal Internal.	Actual External.	Approximate Internal Diameter.			External.	Internal.	External.	Internal.	Metal.	External Surface.	Internal Surface.	
Inch.	Inches.	Inches.	Inches.	No.	Inches.	Inches.	Sq. In.	Sq. In.	Sq. In.	Feet.	Feet.	Pounds
⅛	.405	.205	.1	12½	1.272	.644	.129	.033	.086	9.433	18.632	.29
¼	.54	.294	.123	11	1.696	.924	.229	.068	.161	7.075	12.986	.54
⅜	.675	.421	.127	10½	2.121	1.323	.358	.139	.219	5.657	9.07	.74
½	.84	.542	.149	9	2.639	1.703	.554	.231	.323	4.547	7.046	1.09
¾	1.05	.736	.157	8½	3.299	2.312	.866	.452	.414	3.637	5.109	1.39
1	1.315	.951	.182	7	4.131	2.988	1.358	.71	.648	2.904	4.016	2.17
1¼	1.66	1.272	.194	6½	5.215	3.996	2.164	1.271	.893	2.301	3.003	3.
1½	1.9	1.494	.203	6	5.969	4.694	2.835	1.753	1.082	2.01	2.556	3.63
2	2.375	1.933	.221	5	7.461	6.073	4.43	2.985	1.495	1.608	1.975	5.02
2½	2.875	2.315	.28	2	9.032	7.273	6.492	4.209	2.283	1.328	1.649	7.67
3	3.5	2.892	.304	1	10.996	9.085	9.621	6.569	3.052	1.091	1.328	10.25
3½	4.	3.358	.321	0	12.566	10.549	12.566	8.856	3.71	.955	1.137	12.47
4	4.5	3.818	.341	0	14.137	11.995	15.904	11.449	4.455	.849	1.	14.97
5	5.563	4.813	.375	00	17.477	15.120	24.306	18.193	6.12	.687	.793	20.54
6	6.625	5.75	.437	000	20.813	18.064	34.472	25.967	8.505	.577	.664	28.58

Wrought Iron and Steel Double Extra Strong Pipe.

Table of Standard Dimensions.

Diameter.			Nominal Thickness.	Nearest Wire Gauge.	Circumference.		Transverse Areas.			Length of Pipe per Square Foot of		Nominal Weight per Foot.
Nominal Internal.	Actual External.	Approximate Internal Diameter.			External.	Internal.	External.	Internal.	Metal.	External Surface.	Internal Surface.	
Inch.	Inches.	Inches.	Inches.	No.	Inches.	Inches.	Sq. In.	Sq. In.	Sq. In.	Feet.	Feet.	Pounds
⅛	.84	.244	.298	1	2.639	.766	.554	.047	.507	4.547	15.667	1.7
¼	1.05	.422	.314	1	3.299	1.326	.866	.139	.727	3.637	9.049	2.44
1	1.315	.587	.364	00	4.131	1.844	1.358	.271	1.087	2.904	6.508	3.65
1¼	1.66	.885	.388	00	5.215	2.78	2.164	.615	1.549	2.304	4.317	5.2
1½	1.9	1.088	.406	000	5.969	3.418	2.835	.93	1.905	2.01	3.511	6.4
2	2.375	1.491	.442	0000	7.461	4.684	4.43	1.744	2.686	1.608	2.561	9.02
2½	2.875	1.755	.560	9/16 —	9.032	5.513	6.492	2.419	4.073	1.328	2.176	13.68
3	3.5	2.284	.608	⅝ —	10.996	7.175	9.621	4.097	5.524	1.091	1.672	18.56
3½	4.	2.716	.642	⅝ X	12.566	8.533	12.566	5.794	6.772	.955	1.406	22.75
4	4.5	3.136	.682	11/16 —	14.137	9.852	15.904	7.724	8.18	.849	1.217	27.48
5	5.563	4.063	.75	¾	17.477	12.764	24.306	12.965	11.34	.687	.940	38.12
6	6.625	4.875	.875	⅞	20.813	15.315	34.472	18.666	15.806	.577	.784	53.11

Table Giving Velocity of Flow of Water

In Feet per Minute, Through Pipes of Various Sizes, for Varying Quantities of Flow.

Gallons per Minute.	3-4 inch.	1 inch.	1 1-4 inch.	1 1-2 inch.	2 inch.	2 1-2 inch.	3 inch.	4 inch.
5	218	122½	78½	54½	30½	19½	13½	7¾
10	436	245	157	109	61	38	27	15½
15	653	367½	235½	163½	91½	58½	40½	23
20	872	490	314	218	122	78	54	30¾
25	1090	612½	392½	272½	152½	97½	67½	38½
30		735	451	327	183	117	81	46
35		857½	549½	381½	213½	136½	94½	53¾
40		980	628	436	244	156	108	61½
45		1102½	706½	490½	274½	175½	121½	69
50			785	545	305	195	135	76¾
75			1177½	817½	457½	292½	202½	115
100				1090	610	380	270	153½
125					762½	487½	337½	191¾
150					915	585	405	230
175					1067½	682½	472½	268½
200					1220	780	540	306¾

Table Giving Loss in Pressure

Due to Friction, in Pounds, per Square Inch, for Pipe 100 Feet Long.

Gallons Discharged per Minute.	3-4 inch.	1 inch.	1 1-4 inch.	1 1-2 inch.	2 inch.	2 1-2 inch.	3 inch.	4 inch.
5	3.3	0.84	0.31	0.12				
10	13.0	3.16	1.05	0.47	0.12			
15	28.7	6.98	2.38	0.97	0.27	0.06		
20	50.4	12.3	4.07	1.66	0.42	0.13	0.03	
25	78.0	19.0	6.40	2.62	0.67	0.21	0.10	
30		27.5	9.15	3.75	0.91	0.30	0.12	0.03
35		37.0	12.4	5.05	1.26	0.42	0.14	0.05
40		48.0	16.1	6.52	1.60	0.51	0.17	0.06
45			20.2	8.15	2.01	0.62	0.27	0.07
50			24.9	10.0	2.44	0.81	0.35	0.09
75			56.1	22.4	5.32	1.80	0.74	0.21
100				39.0	9.46	3.20	1.31	0.33
125					14.9	4.89	1.99	0.51
150					21.2	7.0	2.88	0.69
175					28.1	9.46	3.85	0.95
200					37.5	12.47	5.02	1.22

TENSILE STRENGTH OF BOLTS.

Diameter of Bolt in Inches.	Area at Bottom of Thread.	At 7,000 lbs. per square inch.	At 10,000 lbs. per square inch.	At 12,000 lbs. per square inch.	At 15,000 lbs. per square inch.	At 20,000 lbs. per square inch.
½	.125	875	1,250	1,500	1,875	2,500
⅝	.196	1,372	1,960	2,350	2,940	3,920
¾	.3	2,100	3,000	3,600	4,500	6,000
⅞	.42	2,940	4,200	5,040	6,300	8,400
1	.55	3,850	5,500	6,600	8,250	11,000
1⅛	.69	4,830	6,900	8,280	10,350	13,800
1¼	.78	5,460	7,800	9,300	11,700	15,600
1⅜	1.06	7,420	10,600	12,720	15,900	21,200
1½	1.28	8,960	12,800	15,360	19,200	25,600
1⅝	1.53	10,710	15,300	18,360	22,950	30,600
1¾	1.76	12,320	17,600	21,120	26,400	35,200
1⅞	2.03	14,210	20,300	24,360	30,450	40,600
2	2.3	16,100	23,000	27,600	34,500	46,000
2¼	3.12	21,840	31,200	37,440	46,800	62,400
2½	3.7	25,900	37,000	44,400	55,500	74,000

The breaking strength of good American bolt iron is usually taken at 50,000 pounds per square inch, with an elongation of 15 per cent before breaking. It should not set under a strain of less than 25,000 pounds. The proof strain is 20,000 pounds per square inch, and beyond this amount iron should never be strained in practice.

TABLE OF THE PROPERTIES OF SATURATED STEAM.

Gauge pressure in lbs. per sq. in.	Temperature in degrees F.	Total heat units from water at 32° F.	Heat units in liquid from 32° F.	Heat of vaporization in heat units.	Density of weight of 1 cu. ft. in lbs.	Volume of 1 lb. in cubic feet	Weight of 1 cu. ft. of water.
0	212.00	1146.6	180.8	965.8	0.03760	26.60	59.76
							59.64
10	239.36	1154.9	208.4	946.5	0.06128	16.32	59.04
20	258.68	1160.8	227.9	932.9	0.08439	11.85	58.50
30	273.87	1165.5	243.2	922.3	0.1070	9.347	58.07
40	286.54	1169.3	255.9	913.4	0.1292	7.736	57.69
50	297.46	1172.6	266.9	905.7	0.1512	6.612	57.32
55	302.42	1174.2	271.9	902.3	0.1621	6.169	57.22
60	307.10	1175.6	276.6	899.0	0.1729	5.784	57.08
65	311.54	1176.9	281.1	895.8	0.1837	5.443	56.95
70	315 77	1178.2	285.6	892.7	0.1945	5.142	56.82
75	319.80	1179.5	289.8	889.8	0.2052	4.873	56.69
80	323.66	1180.6	293.8	886.9	0.2159	4.633	56.59
85	327.36	1181.8	297.7	884.2	0.2265	4.415	56.47
90	330.92	1182.8	301.5	881.5	0.2371	4.218	56.36
95	334.35	1183.9	305.0	879.0	0.2477	4.037	56.25
100	337.66	1184.9	308.5	876.5	0.2583	3.872	56.18
105	340.86	1185.9	311.8	874.1	0.2689	3.720	56.07
110	343.95	1186.8	315.0	871.8	0.2794	3.580	55.97
115	346.94	1187.7	318.2	869.6	0.2898	3.452	55.87
120	349.85	1188.6	321.2	867.4	0.3003	3.330	55.77
125	352.68	1189.5	324.2	865.3	0.3107	3.219	55.69
130	355.43	1190.3	327.0	863.3	0.3212	3.113	55.58
135	358.10	1191.1	329.8	861.3	0.3315	3.017	55.52
140	360.70	1191.9	332.5	859.4	0.3420	2.924	55.44
145	363.25	1192.8	335.2	857.5	0.3524	2.838	55.36
150	365.73	1193.5	337.8	855.7	0.3629	2.756	55.29
155	368.62	1194.3	340.3	853.9	0.3731	2.681	55.22
160	370.51	1195.0	342.8	852.1	0.3835	2.608	55.15
165	372.83	1195.7	345.2	850.4	0.3939	2.539	55.07
170	375.09	1196.3	347 6	848.7	0.4043	2.474	54.99
175	377.31	1197.0	349.9	847.1	0.4147	2.412	54.93
180	379.48	1197.7	352.2	845.4	0.4251	2.353	54.86
185	381.60	1198.3	354.4	843.9	0.4353	2.297	54.79
190	383.70	1199.0	356.6	842.3	0.4455	2.244	54.73
195	385.75	1199.6	358.8	840.8	0.4559	2.193	54.66
200	387.76	1200.2	360.9	839.2	0.4663	2.145	54.60
225	397.36	1203.1	370.9	832.2	0.5179	1.930	54.27
250	406.07	1205.8	380.1	825.7	0.5699	1.755	54.03
275	414.22	1208.3	388.5	819.8	0.621	1.609	53.77
300	421.83	1210.6	396.5	814.1	0.674	1.482	53.54

Chimneys.

Area Square Feet.	Diameter, Inches.	Heights in Feet.												
		75	80	85	90	95	100	110	120	130	140	150	175	200
		Commercial Horse-Power.												
3.14	24	75	78	81										
3.69	26	90	92	95	98									
4.28	28		106	110	114	117	120							
4.91	30		122	127	130	133	137							
5.59	32			144	149	152	156	164						
6.31	34			162	168	171	176	185						
7.07	36				188	192	198	208	215					
8.73	40					237	244	257	267	279				
10.56	44					287	296	310	322	337				
12.57	48						352	370	384	400	413			
15.90	54						445	468	484	507	526			
19.63	60							577	600	627	650	672		
23.76	66							697	725	758	784	815		
28.27	72								862	902	931	969	1044	
38.48	84								1173	1229	1270	1319	1422	
50.27	96									1584	1660	1725	1859	1983
63.62	108									2058	2102	2181	2852	2511
78.54	120										2596	2693	2904	3100

Reduction of Chimney Draft by Long Flues.

Total Length of Flues, in feet.	50	100	200	400	600	800	1000	2000
Chimney Draft, in per cent.	100	93	79	66	58	52	48	35

Area of Circles.

Diam.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
1/8	0.0123	10	78.54	30	706.86	65	3318.3
1/4	0.0491	10 1/2	86.59	31	754.76	66	3421.2
3/8	0.1104	11	95.03	32	804.24	67	3525.6
1/2	0.1963	11 1/2	103.86	33	855.30	68	3631.6
5/8	0.3068	12	113.09	34	907.92	69	3739.2
3/4	0.4418	12 1/2	122.71	35	962.11	70	3848.4
7/8	0.6013	13	132.73	36	1017.8	71	3959.2
1	0.7854	13 1/2	143.13	37	1075.2	72	4071.5
1 1/8	0.9940	14	153.93	38	1134.1	73	4185.4
1 1/4	1.227	14 1/2	165.13	39	1194.5	74	4300.8
1 3/8	1.484	15	176.71	40	1256.6	75	4417.8
1 1/2	1.767	15 1/2	188.69	41	1320.2	76	4536 4
1 5/8	2.073	16	201.06	42	1385.4	77	4656.6
1 3/4	2.405	16 1/2	213.82	43	1452.2	78	4778.3
1 7/8	2.761	17	226.98	44	1520.5	79	4901.6
2	3.141	17 1/2	240.52	45	1590.4	80	5026.5
2 1/4	3.976	18	254.46	46	1661.9	81	5153.0
2 1/2	4.908	18 1/2	268.80	47	1734.9	82	5281.0
2 3/4	5.939	19	283.52	48	1809.5	83	5410.6
3	7.068	19 1/2	298.64	49	1885.7	84	5541.7
3 1/4	8.295	20	314.16	50	1963.5	85	5674.5
3 1/2	9.621	20 1/2	330.06	51	2042.8	86	5808.8
3 3/4	11.044	21	346.36	52	2123.7	87	5944.6
4	12.566	21 1/2	363.05	53	2206.1	88	6082.1
4 1/2	15.904	22	380.13	54	2290.2	89	6221.1
5	19.635	22 1/2	397.60	55	2375.8	90	6361.7
5 1/2	23.758	23	415.47	56	2463.0	91	6503.9
6	28.274	23 1/2	433.73	57	2551.7	92	6647.6
6 1/2	33.183	24	452.39	58	2642.0	93	6792.9
7	38.484	24 1/2	471.43	59	2733.9	94	6939.8
7 1/2	44.178	25	490.87	60	2827.4	95	7088.2
8	50.265	26	530.93	61	2922.4	96	7238.2
8 1/2	56.745	27	572.55	62	3019.0	97	7389.8
9	63.617	28	615.75	63	3117.2	98	7542.9
9 1/2	70.882	29	660.52	64	3216.9	99	7697.7

To compute the area of a diameter greater than any in the above table:

Rule.—Divide the dimension by 2, 3, 4, etc., if practicable, until it is reduced to a quotient to be found in the table, then multiply the tabular area of the quotient by the square of the factor. The product will be the area required.

Example.—What is area of diameter of 150? $150 \div 5 = 30$. Tabular area of $30 = 706.86$ which $\times 25 = 17{,}671.5$ area required.

CIRCUMFERENCE OF CIRCLES.

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
⅛	.3927	10	31.41	30	94.24	65	204.2
¼	.7854	10½	32.98	31	97.38	66	207.3
⅜	1.178	11	34.55	32	100.5	67	210.4
½	1.570	11½	36.12	33	103.6	68	213.6
⅝	1.963	12	37.69	34	106.8	69	216.7
¾	2.356	12½	39.27	35	109.9	70	219.9
⅞	2.748	13	40.84	36	113.0	71	223.0
1	3.141	13½	42.41	37	116.2	72	226.1
1⅛	3.534	14	43.98	38	119.3	73	229.3
1¼	3.927	14½	45.55	39	122.5	74	232.4
1⅜	4.319	15	47.12	40	125.6	75	235.6
1½	4.712	15½	48.69	41	128.8	76	238.7
1⅝	5.105	16	50.26	42	131.9	77	241.9
1¾	5.497	16½	51.83	43	135.0	78	245.0
1⅞	5.890	17	53.40	44	138.2	79	248.1
2	6.283	17½	54.97	45	141.3	80	251.3
2¼	7.068	18	56.54	46	144.5	81	254.4
2½	7.854	18½	58.11	47	147.6	82	257.6
2¾	8.639	19	59.69	48	150.7	83	260.7
3	9.424	19½	61.26	49	153.9	84	263.8
3¼	10.21	20	62.83	50	157.0	85	267.0
3½	10.99	20½	64.40	51	160.2	86	270.1
3¾	11.78	21	65.97	52	163.3	87	273.3
4	12.56	21½	67.54	53	166.5	88	276.4
4½	14.13	22	69.11	54	169.6	89	279.6
5	15.70	22½	70.68	55	172.7	90	282.7
5½	17.27	23	72.25	56	175.9	91	285.8
6	18.84	23½	73.82	57	179.0	92	289.0
6½	20.42	24	75.39	58	182.2	93	292.1
7	21.99	24½	76.96	59	185.3	94	295.3
7½	23.56	25	78.54	60	188.4	95	298.4
8	25.13	26	81.68	61	191.6	96	301.5
8½	26.70	27	84.82	62	194.7	97	304.7
9	28.27	28	87.96	63	197.9	98	307.8
9½	29.84	29	91.10	64	201.0	99	311.0

To compute the circumference of a diameter greater than any in the above table:

RULE.—Divide the dimension by 2, 3, 4, etc., if practicable, until it is reduced to a diameter to be found in table. Take the tabular circumference of this diameter, multiply it by 2, 3, 4, etc., according as it was divided, and the product will be the circumference required.

EXAMPLE.—What is the circumference of a diameter of 125? 125 ÷ 5 = 25. Tabular circumference of 25 = 78.54, 78.54 × 5 = 392.7, circumference required.

PROPERTIES OF METALS.

	Melting Point. Degrees Fahrenheit.	Weight in Lbs. per Cubic Foot.	Weight in Lbs. per Cubic Inch.	Tensile Strength in Pounds per Square Inch.
Aluminum	1140	166 .5	.0963	15000-30000
Antimony	810-1000	421.6	.2439	1050
Brass (average)	1500-1700	523.2	.3027	30000-45000
Copper	1930	552.	.3195	30000-40000
Gold (pure)	2100	1200.9	.6949	20380
Iron, cast	1900-2200	450.	.2604	20000-35000
Iron, wrought	2700-2830	480.	.2779	35000-60000
Lead	618	709.7	.4106	1000-3000
Mercury	39	846.8	.4900	
Nickel	2800	548.7	.3175	
Silver (pure)	1800	655.1	.3791	40000
Steel	2370-2685	489.6	.2834	50000-120000
Tin	475	458.3	.2652	5000
Zinc	780	436.5	.2526	3500

NOTE.—The wide variations in the tensile strength are due to the different forms and qualities of the metal tested. In the case of lead, the lowest strength is for lead cast in a mould, the highest for wire drawn after numerous workings of the metal. With steel it varies with the percentage of carbon used, which is varied according to the grade of steel required. Mercury becomes solid at 39 degrees below zero.

Decimal Parts of an Inch.

1-64	.01563	11-32	.34375	43-64	.67188
1-32	.03125	23-64	.35938	11-16	.6875
3-64	.04688	3-8	.375		
1-16	.0625			45-64	.70313
		25-64	.39063	23-32	.71875
5-64	.07813	13-32	.40625	47-64	.73438
3-32	.09375	27-64	.42188	3-4	.75
7-64	.10938	7-16	.4375		
1-8	.125			49-64	.76563
		29-64	.45313	25-32	.78125
9-64	.14063	15-32	.46875	51-64	.79688
5-32	.15625	31-64	.48438	13-16	.8125
11-64	.17188	1-2	.5		
3-16	.1875			53-64	.82813
		33-64	.51563	27-32	.84375
13-64	.20313	17-32	.53125	55-64	.85938
7-32	.21875	35-64	.54688	7-8	.875
15-64	.23438	9-16	.5625		
1-4	.25			57-64	.89063
		37-64	.57813	29-32	.90625
17-64	.26563	19-32	.59375	59-64	.92188
9-32	.28125	39-64	.60938	15-16	.9375
19-64	.29688	5-8	.625		
5-16	.3125			61-64	.95313
		41-64	.64063	31-32	.96875
21-64	.32813	21-32	.65625	63-64	.97438

Melting Points of Alloys of Tin, Lead, and Bismuth.

Tin.	Lead.	Bismuth.	Melting Point in Degrees Fahrenheit.	Tin.	Lead.	Bismuth.	Melting Point in Degrees Fahrenheit.
2	3	5	199	4	1		372
1	1	4	201	5	1		381
3	2	5	212	2	1		385
4	1	5	246	3		1	392
1		1	286	1	1		466
2		1	334	1	3		552
3	1		367				

MELTING, BOILING AND FREEZING POINTS IN DEGREES FAHRENHEIT OF VARIOUS SUBSTANCES.

Substance.	Melts at Degrees	Substance.	Melts at Degrees
Platinum	3080	Antimony	810
Wrought-Iron	2880	Zinc	780
Nickel	2800	Lead	618
Steel	2600	Bismuth	476
Cast-Iron	2200	Tin	475
Gold (pure)	2100	Cadmium	442
Copper	1930	Sulphur	226
Gun Metal	1960	Bees-Wax	151
Brass	1900	Spermaceti	142
Silver (pure)	1800	Tallow	72
Aluminum	1140	Mercury	39

Substance.	Boils at Degrees	Substance.	Freezes at Degrees
Mercury	660	Olive Oil	36
Linseed Oil	600	Fresh Water	32
Sulphuric Acid	590	Vinegar	28
Oil of Turpentine	560	Sea Water	27½
Nitric Acid	242	Turpentine	14
Sea Water	213	Sulphuric Acid	1
Fresh Water	212		

VACUUM SYSTEM OF STEAM HEATING.

The application of vacuum to steam heating ordinarily involves the employment of a vacuum pump located at, or as near as possible to the lowest point in the return pipe system in which a partial vacuum is to be maintained in order to assist in steam circulation. With such a system properly designed, which means with the return lines graded so that the condensation flows naturally back to the vacuum pump, and with efficient apparatus installed at the proper points, the pump can be of relatively small size as it has little to do beside partially exhausting the air from the piping and radiators so as to establish a lower pressure on the return side of the system. This removal of air once accomplished, the pump has only to handle the condensation and entrained air; the steam condensing in the radiation produces the necessary vacuum to induce a further supply of steam to the heating units. It is only when the physical conditions of the building to be heated make it necessary to have drainage points below the level of the suction inlet of the pump that it is required to "lift" the condensation or return water, but, since the steam used to actuate

ially adapted to vacuum system service, which means that the diaphragm should be of ample area to secure sensitive operation. In the case of boiler pressures above 125 pounds it is the best

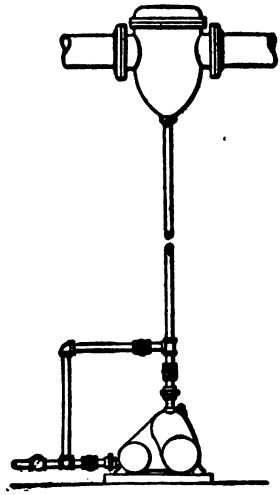


Fig. 104.—Typical method of draining Webster Oil Separator through a Webster Grease Trap.

practice to "step down" the pressure through two reducing valves rather than to make a full reduction with a single valve. By this method more accurate regulation is secured.

Radiation.—Before the supply and return piping can be properly sized and arranged, the amount of heat loss should be carefully calculated for the various rooms and compartments. For

this purpose the rules and tables given elsewhere in this book will be found entirely reliable and satisfactory and apply to any heating system. The rate of condensation varies not only with the type of radiation, but with its location and use.

Ordinary cast-iron loop radiators such as are shown on pages 46 to 50 are most frequently used, except in factories, large ware rooms, etc., where

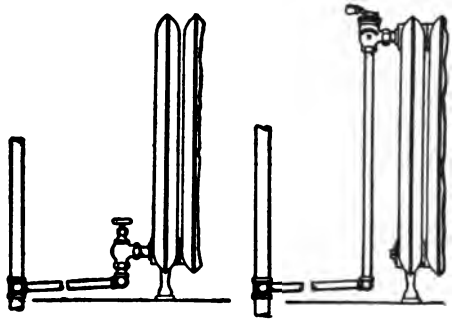


Fig. 105.—Radiator Connections—steam type with bottom connected supply valve. Hot water type with top connected Webster Modulation Valve.

cast-iron wall radiators or ordinary pipe coils may be better adapted. When the riser connections are above the floor line the radiators should be placed so as to secure proper grading of supply and return run-outs from radiators to risers. This may be accomplished as shown in Figure 105.

Radiator Tappings.—The tables here presented are furnished by Warren Webster & Co. and apply to vacuum system only.

The Webster modulation valve referred to in the table of radiator tappings and also shown at the top in Figure 105, is a device especially adapted to vacuum heating systems, and will be described and illustrated later on.

Its function is to regulate the supply of steam as needed.

CAST IRON RADIATOR TAPPINGS.

Table of Sizes.

Square feet of direct radiating surface condensing normally not to exceed ¼ lb. per square foot per hour.	Normal Maximum pounds of condensation per hour.	Supply tapping with Webster Modulation valve attached.	Pipe size of return tapping.
1 to 25	7	¾ in.	½ in.
26 to 50	13	¾ in.	½ in.
51 to 100	25	¾ in.	½ in.
101 to 175	44	¾ in. to 1 in.	½ in.
176 and over	75	1 in.	¾ in.

PIPE COIL TAPPINGS.

Table of Sizes.

Square feet of direct radiating surface condensing normally not to exceed ¼ lb. per square foot per hour.	Normal maximum pounds of condensation per hour.	Pipe size of supply tapping.	Pipe size of return tapping.
42	13	¾ in.	½ in.
84	25	1 in.	½ in.
146	44	1¼ in.	½ in.
250	75	1½ in.	¾ in.
528	158	2 in.	¾ in.
924	277	2½ in.	1 in.

When the radiators are located so that a higher condensation rate will be secured, the sizes of the tappings should be based upon the condensation rate and not upon the size of the radiator.

Direct-indirect radiators will condense at least 33 per cent more than direct radiators. The condensation rate of wall radiators is approximately 0.3 lb. per square foot of radiating surface.

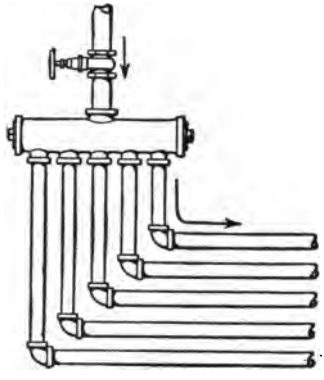


Fig. 106.—When the "harp" coil has but a few pipes, a simple supply connection, as shown, should be made.

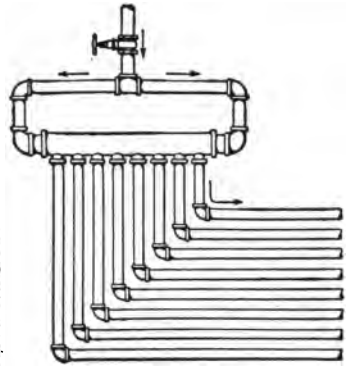


Fig. 107.—Proper method of making supply connections to "harp" coil of large size to insure supply of steam to each pipe in the coil.

Run-Outs.—When horizontal supply run-outs above floor level from risers to radiators are more than four feet in length, they should be at least one size larger than the radiator supply trappings given in the tables. In buildings where it is necessary to lay supply run-outs for some distance, practically level under finished floors, these run-outs must be of such size that the velocity of steam

in the direction opposite to the flow of condensation will not prevent the latter from flowing back to the main. It is good practice to make the return run-outs from radiators to risers not smaller than ¾-inch, even when the radiator return tapping is ½-inch, as the larger pipe is not so liable to become distorted, sagged or clogged.

Pipe Coil Connections.—Figures 106 and 107 show proper methods of making supply connections to harp coils. Figure 108 shows the supply connection to a manifold coil.

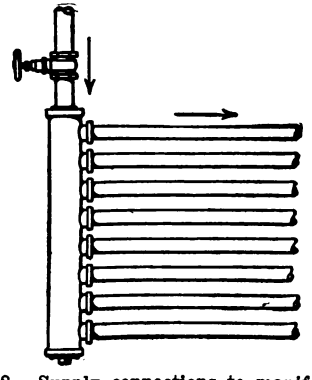


Fig. 108.—Supply connections to manifold coil.

Arrangement of Supply Piping.—There are two general methods in use, the up-feed and down-feed systems. The most common arrangement is the up-feed system of risers, locating the supply mains in the basement.

Where conditions require that the main be run centrally with lateral branches of considerable

length it is customary to drip these branches at the base of each riser. The removal of condensation at these points is accomplished either through individual traps discharging into the vacuum return line as shown in Figures 109 and

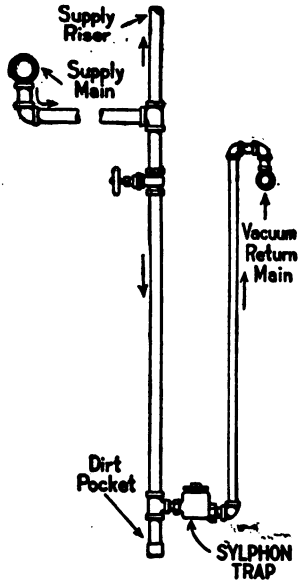


Fig. 109.—Method of dripping supply risers through Webster Sylphon Trap into vacuum return line.

109[a], or by combining these drips into a separate drip line from which the condensation is discharged into the vacuum return line through a heavy duty water line trap as shown in Figure 110.

Down-Feed System.—It is frequently better engineering practice to use the down-feed system, especially in high buildings when the main exhaust pipe leads to the roof. This pipe may be used as the main supply riser, and in such case the back pressure valve is located at or near the top of the main riser, below which a branch is taken off to feed a system of distributing mains to supply the down-feed risers as shown in Figure 111.

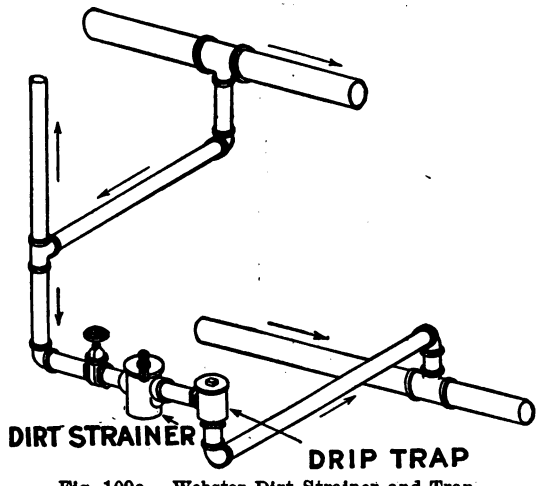


Fig. 109a.—Webster Dirt Strainer and Trap.

These risers may be dripped through individual traps, or the drips may be combined into a separate drip line and discharged through a heavy duty trap into the vacuum return line.

Vacuum Return Lines.—The location and arrangement of return piping is the same whether

the up-feed or down-feed system of supply is used. There should always be a slight downward pitch in the direction of the flow of condensation.

The size of vacuum return piping is affected by the amount of vapor to be handled.

In gravity heating systems the returns are filled with steam, while in vacuum systems with efficient traps they are not so filled.

Assuming the supply piping to be correctly proportioned, a safely approximate rule is to make

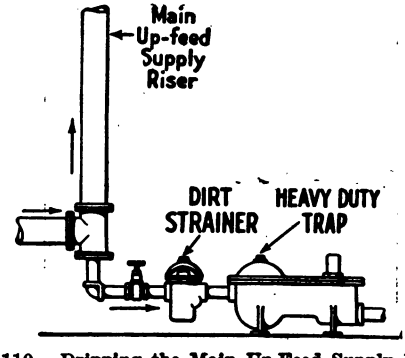


Fig. 110.—Dripping the Main Up-Feed Supply Riser.

the diameter of the horizontal return line not less than one-half the diameter of the corresponding supply line for supply lines of 4-inch and under, while for larger supplies the proportion may be reduced until with a 12-inch supply line for example, a 4-inch return (1/3 supply) would be ample. In no case should a horizontal return pipe less than ¾-inch in size be used for more than

one radiator. "Lifts" in return lines should be avoided when it is possible to arrange for gravity flow to the vacuum pump. When a lift of 6 feet or over cannot be avoided it should be divided into "steps" rather than make the total lift in one rise.

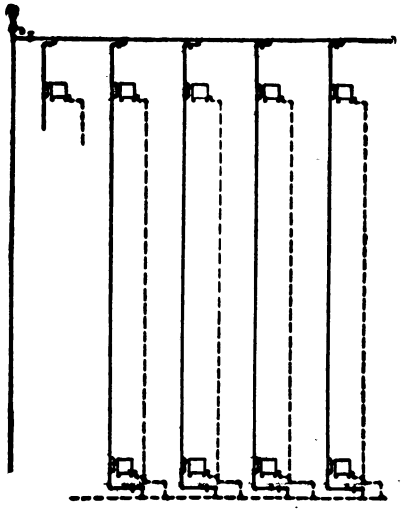


Fig. 111.—The Down-Feed System of Piping.

Exhausting Apparatus.—The highest authorities recommend the installation of two vacuum pumps, each of ample capacity for the entire plant, so that either pump may be cleaned and repaired while the other is in operation.

Modulation Valve.—Mention has already been made of this valve, a sectional view of which is

Fig. 112.—Webster Type N Modulation Valve, sectional view.

Fig. 113.—Webster Water-Seal Trap.

shown in Fig. 112. Its proper location in the steam supply leading to a radiator is shown in Fig. 105.

In Figure 114 is shown a sectional view of the Webster sylphon trap which operates on the well-known thermostatic principle, using a sylphon bellows constructed of seamless brass folds the contraction or expansion of which serves to open or close the valve shown at the bottom.

Fig. 114.—Webster Sylphon Trap.

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